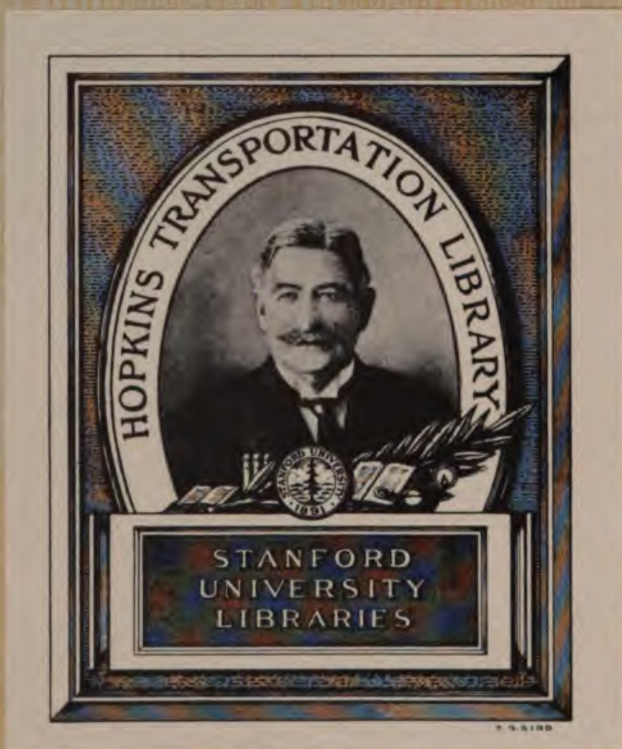
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OBSERVATIONS

ON THE

VARIOUS SYSTEMS

OF

CANAL NAVIGATION,

WITH

INFERENCES PRACTICAL AND MATHEMATICAL;

IN WHICH

Mr. FULTON'S PLAN

OF

WHEEL-BOATS,

AND THE UTILITY OF SUBTERRANEOUS AND OF SMALL CANALS ARE PARTICULARLY INVESTIGATED,

INCLUDING AN ACCOUNT OF THE

CANALS AND INCLINED PLANES OF CHINA.

WITH FOUR PLATES.

BY WILLIAM CHAPMAN,

MEMBER OF THE SOCIETY OF CIVIL ENGINEERS IN LONDON, AND M. R. I. A.

LONDON:

PUBLISHED BY I. AND J. TAYLOR, AT THE ARCHITECTURAL LIBRARY, HIGH HOLBORN.

1797.

TO

HIS GRACE

FRANCIS DUKE OF BRIDGEWATER,

THESE OBSERVATIONS ARE INSCRIBED,

AS A MARK OF THE

AUTHOR'S VENERATION

FOR THE

DIGNIFIED CHARACTER,

TO WHOSE GREAT EXAMPLE

THE CANALS OF THESE KINGDOMS

OWE THEIR ORIGIN:

FROM WHICH HAVE RESULTED

MUCH OF

THE COMMERCIAL AND POLITICAL IMPORTANCE

OF THIS

EMPIRE.

Newcastle-upon-Tyne, 1797.

CONTENTS.

ERRATA.

THE Author's reſidence being at a conſiderable diſtance from the Preſs, he begs indulgence for the following Corrections and Additions:

Page 3 line 6, from the bottom, for *is* read *are*.
The Note in this Page was written before Sir G. Staunton's account of the Embaſſy to China was publiſhed; and as there is no mention in that work of the Chineſe uſing cradles with their inclined planes, that idea muſt of courſe be relinquiſhed.
Page 4, laſt line, tome 1 read tome 4.
5 13, for *other* read *upper*.
5, addition to the Note. In the inclined plane at Ketley, the general inclination, as I was informed by Mr. Reynolds, is nearly 22°, and at the extremities 11°½: beſides which, the declivity of the boat was further reduced by a difference in the diameters of the wheels, and alſo by the frame being raiſed higher above the axle-tree at the deſcending end.
Page 9 line 15, for *or trough* read *a trough*.
28 11, for *becauſe the* read *becauſe of the*.
31 9, for *as to* read *as conſiderably to*.
32 10, for *axes* read *axis*.
36 6, in the middle column, for *poſition* read *depth*.
38 10, for *giving* read *given*.
39 9, for *l k* read *e k*.
49 6, for *reſting power* read *reſiſting power*.
57 8, from bottom, for *ſection* read *ſecant*.
62 6, from bottom, for *ſnow* read *ſnows*.
67 9, for *article* read *vehicle*.
73 12, from bottom, for *tracked* read *tracked againſt*.
76 15, for *given* read *giving*; and line 21, for *other* read *over*.
To theſe might be added, ſeveral ſmall typographic errors, which being ſufficiently apparent for the reader to correct, are omitted.

OBSER-

OBSERVATIONS

ON VARIOUS SYSTEMS OF

CANAL NAVIGATION.

CHAP. I.

Introduction.—Description of various Means of overcoming Ascent and Descent in Canals and Rivers.

SEVERAL ages probably elapsed before the necessities of mankind caused the introduction of highways and bridges; these would be adequate to every purpose, long after they united into nations, and became stationary in their residence; as they would fix themselves in such places where their wants could easily be supplied, or where navigable rivers would afford the means of exchanging the produce of their industry. But, when increase of numbers induced them to settle in less favorable situations, and called forth their bodily and mental exertions; the necessity of reducing the vast charge of distant conveyance of heavy articles, would point out the eligibility, and eventually the means, of obtaining water carriage, in many places where rivers had not admitted it. Thus Canals began their existence, at remote periods, in the populous countries of China and Egypt; and were adopted by the Romans in many parts of their extended empire, and were introduced by them, into this island, in the fenny country east of the river Trent. Those Canals were, necessarily, on long continued levels; and the communications, either between them or to navigable rivers, required land carriage. This inconvenience, during the course of numerous ages, could not fail attracting the attention of ingenious men; and, accordingly, they devised various means of overcoming ascent, both in Rivers and Canals.

 It,

It, consequently, is an object of importance, to record all such progressive improvements as have come to the knowlege of any individual; and to investigate every new proposition; as, by a fair discussion, many plans may be introduced to the extent they merit, which might otherwise lie dormant through prejudice, or the caution requisite in all great undertakings: and, on the other hand, it may prevent enthusiasm for plausible systems from misleading, and carrying away, their followers beyond what may be useful.

No system can ever be so perfect, as to be unbounded in the propriety of application; and, therefore, the mode of overcoming ascent and descent by Locks, which is, undoubtedly, a noble invention, and almost generally useful, is not without its limits, as to utility. Having conceded this point, which every impartial man must do; I feel myself more at liberty to controvert the opinion thrown out by Mr. Fulton, in his Treatise on the Improvement of Canals, that Locks will in future be found to be ineligible in all cases; and be superseded by some system similar to what he has laid down.

His plan possesses much ingenuity; but, like others, is necessarily limited in the propriety of its application: and the extent of those limits is what I shall endeavour to explain.

Those who adopt any favorite system on practical subjects, without the aid of experience to guide them, are liable to be carried away by the warmth of their imagination; and are led to apprehend they have attained a something of universal application: To this alone I can attribute Mr. Fulton's reprobation of Locks, so useful for facilitating internal Navigation, and which the experience of three * centuries has barely brought to perfection. Previously to the commencement of this period, and down to the present

* The first Lock was supposed to be erected in the year 1488, upon the Brenta nigh Padua. Immediately afterwards the two Canals of Milan, between which there was nearly 34 feet fall, were joined by means of 6 Locks. *Traité des Canaux de Navigation, par M. de la Lande.*

time,

time, the communication between different levels interrupted by fall of ground, by cataracts, or by rapids impracticable to haul boats up, or by intervening high land, has been effected various ways.

1st. By portage of the articles from one level to another, and carriage of the boat itself, as is practised in various parts of North America; for instance, at the falls of the Mohawk, the portage from that river to Wood Creek, and the falls of the Onandaga; and even in our own island at the Isthmus of Tarbet in the Mull of Cantyre. This mode is also practised between Tarbet on Loch Lomond, and Arrachar at the head of Loch Long; at the Tarbet of Jura, and at all the other Tarbets in the Isles and Highlands: the word Tarbet is derived from two Celtic words, implying the drawing or hauling of a boat; it denotes a low narrow neck of land between two separate waters, or two arms of the same sea or lake.

2d. By hauling the empty boats up the rapids when discharged of their cargoes; and conveying the latter by land.

3d. By making the rapids themselves navigable by contraction; and, where necessary, affixing machinery to haul up the boats.

4th. By stopping the water of a river for a time, and letting it off to occasion an artificial flood; as is yet practised on the Cam and other rivers.

5th. By Ponts aux Rouleaux, or inclined planes, with rollers at short distances, over which, by means of a water wheel, the boats are hove up to the ridge separating the two waters (viz. a little above the level of the highest), and launched, or regularly let down, to the pool or level they are proceeding to. The boats in this method could not be very long, because, although, in ascending or descending the inclined plane, they might bear upon many rollers; yet, in the change of position from the regular line of ascent, they must obviously bear upon one roller, and be liable to strain *.

In-

* The same inconvenience must attend the Chinese method, which, of late, is said in some instances to differ only by the intervention of a cradle between the boat and the rollers.

In an anonymous * Treatife, publifhed in Paris in the year 1693, this mode by rollers is particularly defcribed, and faid to have been practifed for fome time in Holland, with much fuccefs; and that there was a conftruction of that kind in the Canal between Amfterdam and Sardam.

6th. The method recommended by Mr. Leach, land furveyor (in his Treatife on Inland Navigation), who lays claim to the invention (in the year 1774), of connecting long continued levels, by inclined planes, which he propofes to be double parallel planes; and furnifhed with rollers, on which caiffons capable of containing water of fuperior weight to a loaded boat were to move alternately up and down. The boats at the bottom level were to float over thefe caiffons, which, in their paffage up or down the planes with the boats upon them, were to be full or empty as the circumftance might require.

The top of this caiffon is horizontal, and furnifhed with rollers, fo that when it arrives at the ridge, or fummit of the inclined plane, penning up the higher water, the boat may from thence be launched into the upper Canal.

7th. The fyftem lately introduced into this kingdom by Mr. William Reynolds of Ketley, viz. that of connecting, as in the preceding inftance, different levels of Canals, of great intervening height, by means of an inclined plane, with two parallel rail-ways; up and down which, by the aid of a rope paffing over a wheel at the head of the plane, boats of 8 tons burthen alternately pafs upon carriages, over which they are floated at each extremity of the fall. The loaded boat (the trade being defcending) draws up a light boat, or occafionally a half laden one. The firft of thefe works was at Ketley in Shropfhire. The carriage downwards was principally coals, and about four hundred tons daily.

lers. According to Magelhaens (as quoted by Belidor, Architect. Hydraul. t. 4. p. 355 & 356) the Chinefe method was to haul the veffels by the power of capftans, or by the immediate effort of 4 or 500 men, up contracted channels where the water ran with great rapidity, and was confined by mafonry. He alfo defcribes the dry inclined planes for fmaller boats.

* *Traité des Moyens de rendre les Rivieres navigable.* This mode is alfo mentioned in Belidor, Architect. Hydraul, tom. 1.

The

The boats were rectangular boxes of 20 feet in length, 6 feet width, and nearly 4 feet height; and one horse drew fifteen of them, connected to each other by a few links of chain.

The chief difficulty in going from a higher to a lower level, without waste of water, lay in passing the ridge, or dam, which retains the water at the end of the upper level. This he overcame two ways.

In the first method, which he carried into effect about seven years since, he avoided the ascent from the upper level to the ridge holding up the water, by the means of two parallel Locks at the head of the inclined plane; into one of which the laden boat floated on its carriage; and the light boat, when ascended into the other, was by the admission of water floated off. The water consumed in these Locks was let into a side reservoir, and in dry seasons pumped back by a steam engine to the other level. Mr. Reynolds has great merit in the invention of this method.

The second method, as practised, at the inclined plane below the iron bridge at Broseley, in Shropshire, differs from the former in having no Locks, and the boats being drawn upon the ridge by a steam engine; which also occasionally draws up the light boats, without waiting for the laden ones. The boats, as in the other, are floated upon four-wheeled carriages *, which ascend and descend alternately.

The merit of this invention, or, at least, the first introducing it into practice (which was I believe totally unknown to Mr. Reynolds) is due to the late Mr. Davis Dukart, an Engineer in the Sardinian service, who settled in Ireland, and became engaged in the Tyrone collieries. These collieries are less than a mile North of Dungannon, and about three miles from the colliery bason, at the head of a Canal ascending by eight Locks

* A leading feature of difference of effect between these two methods, is, that the former is applicable to steeper descents and longer boats; because the frame of the carriage may at its descending end be elevated from the inclined plane to any extent; which if done so considerably, in the latter method, would dip the opposite end of the boat in coming in or going out of the upper Canal.

from

from the river Blackwater, near its junction with Lough Neagh. The rise from the bason to the colliery, was little short of 200 feet ; and after attempting, very improperly for the particular instance, to conquer this great ascent in that short space, by continuing the Lock Navigation ; and finding the sums granted by Government for that purpose inadequate to the design ; he turned his attention to small boats, and inclined planes, of which he constructed three, connected by narrow Canals. The falls were seventy, sixty, and fifty-five feet, which last terminated about 15 feet above the colliery bason ; from which by a short railway, his boats, again floating over a carriage, were drawn onwards to the wharf, where the railway was supported on geers, or frames, and the boats were turned over to discharge their cargoes. They were calculated to carry, each, a ton of the measure the coals were sold by, viz. (about 27 cwt.) which they did at less than 18 inches draught, so that his Canal might be every where fordable ; and, accordingly, no bridges were erected on it.

The boats were flat bottomed, and upright at the sides and ends : their width was $4\frac{1}{2}$ feet, their height 2 feet 6 inches, and 10 feet straight side : one end was square, and the other pointed, so as to form a right angle at the stem ; and they went, as in all similar cases, a number of them chained after each other.

His first attempt differed from the " Ponts aux Rouleaux" in no other respect than having a double passage down his inclined planes ; so that, by means of a rope leading over a wheel, his loaded boats drew up his light ones :—but finding various inconveniences from some of the rollers not turning, and from the individual inequality of the diameters of others throwing his boats to one side, as well as from other causes ; he suggested and put in use, the method now practised on the banks of the Severn, of having a cradle or frame with four wheels, brought under his boats ; upon which, over a double railway, they alternately ascended ; the sole difference between the two methods being in the size of his boats ; and that, in place of a steam engine, he made use of a horse gin to draw his boats upon the ridge terminating the upper level.

This

This work was executed a little prior to the year 1777; but, excepting in passing a few boats by way of trial, nothing more was done, as Mr. Dukart could not obtain money to complete some of the intervening levels, and died soon after the time mentioned. The works were then entirely laid aside; and, a few years since, a common rail road, cutting off a considerable portion of the distance, has with propriety been adopted in their stead.

8th. The method suggested by the Earl of Stanhope in 1793, viz. the connecting different levels of Canal by iron rail-roads of a gradual and easy ascent; up and down which small boats were to pass suspended between a pair of wheels of about 6 feet diameter.

9th. The following invention, which is likewise ascribed to his Lordship, viz. the passing of boats, up or down an inclined plane, on rollers moving with the boats for half their length, in which space the boats would pass over them. The rollers are then to return to their places, by means of weights acting over pulleys, and connected by a chain to the ends of each roller. This method, undoubtedly, would be attended with considerable expence in the execution; but has the merit of getting quit of the friction of rollers moving on gudgeons. It must however possess the other inconveniences of the "Ponts aux Rouleaux." The most material of these are that the boats must rest on a single roller in the convex part of the road; unless all convexity be avoided by having a lock at the head of the inclined plane; in which case the ascent must be very gentle or the boat be short, or high at the ends, to enable her to float from her reclined position. If the way be very steep, a frame for the boat to rest on, and raised at the lower end, would be requisite.

A method of using moving rollers attached to such a frame has been suggested by Mr. Fulton. He proposes to connect them, by the gudgeons at their ends passing through an endless chain, or collar, and thus returning the rollers over the frame, but under the boat.

By

By the former method, the frame, or boat, muft frequently reft only on two rollers; but in this they may be as clofe to each other as requifite: and by having in place of one fet, a fet of rollers on each fide, this method (with a regular declivity of plane and locks at the head of it) is capable of being carried into effect for boats of any magnitude fuitable for paffing on inclined planes.

10th. The method publifhed by Dr. Anderfon of Edinburgh, in "The General View of the Agriculture and Rural Œconomy of the County of Aberdeen, for the year 1794."

The Doctor, there, obferves that, for all the purpofes of commerce, no more width of boat is requifite than four feet; or more than two or three feet depth; and that the length might be indefinite fo as not to be inconvenient for afcending and defcending between any two levels of Canal; which he propofes to be done in the following manner, viz. that the lower level be run up to nearly under the end of the upper, and terminate by an upright end, and two fide walls of mafonry, to the full height of the fall; with a pier in the middle, dividing the paffage between the two fide walls, into two openings of rather greater width than the boat: the two ends of this pier are to be elevated fo as to fuftain the axis of a wheel of a diameter equal to the width of the pier, and half of each opening. A chain paffing over the wheel, fufpends, from each end, a rectangular cafe fo hung that when one fhall be at the bottom ready for a boat to float into; the other fhall be at the top, and clofe preffed to the wall or frame at the end of the Canal, fo as to prevent the efcape of water: then, by opening a ftop-gate at the end of either Canal, and another at the correfponding end of the cafe, it is obvious that the boat may float in or out. The lower boat and cafe (or cafe with water only) are then in a kind of Lock, juft containing the cafe, and of fufficient depth to permit it to defcend to the level of the lower Canal. From this Lock there is a conduit to keep the water down below the Canal bottom.

Thefe are the outlines of the invention; which, where the connection between the two levels is a precipice, or fo fteep as to require only a fhort tunnel

tunnel to the well, or pit, up or down which the boats are to move, may, on receiving ſuch improvements as it is capable of, be eaſily carried into effect for ſmall boats; for which alone the author propoſes it.

It is obvious that, under other circumſtances as to ſituation, the expences of high embankments above, of deep ſinking below, and of bringing up the conduit to lay dry the lower locks, muſt more than counterbalance any advantage that can be derived from it.

11th. Meſſrs. Rowland and Pickering's plan of enabling great boats to aſcend and deſcend with inconſiderable waſte of water. This conſiſts in having, at the head of the lower level of Canal, a pit ſunk as much below the bottom of it, as the difference of height between the two levels, added to the depth of a covered caiſſon of requiſite magnitude. This caiſſon, when immerſed in the water, with which the pit is filled to the level of the bottom of the Canal, is to ſupport, on wooden or iron pillars of height equal to the fall between the two levels, or trough or cradle, with gates or draw doors at each end; containing a ſufficient depth of water, to which the floating power of the caiſſon muſt then be in equilibrio; and, conſequently, capable of moving with eaſe between the top and bottom of the pit.

When the ſurface of the water of the cradle is level with either of the Canals, and the end of it cloſed againſt the framing of the gate of the Canal, by ſcrews, or other means; and the water let in to fill the vacancy between the gate of the cradle and that of the Canal, they both may then be opened, and a boat be admitted, or paſs out.

Excepting what may, if neceſſary, be uſed for regulating the equipoiſe and change of motion; the intermediate water between the gate of each level and that of the cradle, is all that is conſumed; and with draw doors to the cradle and ſingle gates to each level, as already premiſed, the quantity muſt be very trivial. The weight of water diſplaced by the bulk of the pillars ſuſtaining the cradle, need not be material; and, where requiſite, it is propoſed to be counterbalanced by weights acting on a ſpiral wheel.

 This

This plan, which poſſeſſes ingenuity, and is applicable in many inſtances, is now carried into execution on the Elleſmere Canal, near Ruabon in Denbighſhire; on a fall of 12 feet, and for boats of 70 feet length, and ſeven feet width; and the whole is moved up and down by a rack and pinion towards each end of the machine.

Meſſrs. Rowland and Pickering's invention alſo extends to another principle; that of counterbalancing the cradle containing the boat by weight; which, if carried to the perfection it is capable of, will in high falls have decided advantages.

12th. Mr. Weldon's Caiſſon Lock, or Diving Cheſt, in which boats with their cargoes are to deſcend, to a conſiderable depth, down a pit or well; and afterwards paſs by a tunnel into a lower Canal: and to aſcend in a ſimilar manner.

This method is now carrying into effect on the Somerſetſhire Coal Canal at Monkton Comb near Bath, on a fall of about 45 feet, and for boats of 72 feet length, and ſeven feet width.

The caiſſon, or cheſt, is cylindric; and, in this inſtance, of ſufficient ſtrength to bear the preſſure of a column of water 54 feet, or upwards; to which it is ſubjected, when oppoſite the lower level, on account of the neceſſity of its being covered when oppoſed to the entrance of the upper level. It is ſo balanced that when it has ſufficient water within it to float a boat, it is of the ſame ſpecific gravity as the medium it floats in: and, like an air balloon, it aſcends or deſcends by a ſlight increaſe, or diminution of its relative gravity; which, in this machine, is done by raiſing out, or admitting an inconſiderable quantity of water. The pit, in which the diving cheſt moves, has, oppoſite each level of Canal, a tunnel or opening cloſed with gates; and is ſo much higher than the upper Canal as to contain a height of water juſt ſufficient, as already mentioned, to cover the caiſſon when oppoſite the upper level. In this, or in its lower poſition, when run cloſe to, and abutting againſt, the entrance, it is retained by the water being let out of the ſhort part of the tunnel between the gates of the level, and the end

end of the caiſſon. It is then held there by the preſſure of the column of water intervening between the ſurface of the pit and that of the Canal to which it is oppoſed. The gates of the level and Canal are then opened, and the boat goes in or out; and, on the gates being again cloſed, and the water let into the vacancy, the diving cheſt is ready to proceed to the other level.

This ſcheme poſſeſſes much originality, and may often be uſefully applied. It and the preceding one are ſecured to their reſpective inventors by patents; therefore I ſhall refrain from giving my ſentiments on the ſeparate advantages of each, and from pointing out the inſtances in which either might have the preference of the other. In general, all methods of aſcending and deſcending which ſave water, where the want of it for other purpoſes, whether for giving motion to machinery, or the irrigation of land, would be greater than the advantage the navigation would obtain by the uſe of it, muſt clearly be ſo far beneficial to the community.

13th. The laſt method * introduced to the public, is the one which has principally occaſioned this Eſſay, viz. Mr. Fulton's wheel boats; which, when applied to inclined planes, he looks upon as paramount to all other modes. The novelty of this method conſiſts principally in having † wheels affixed to, or underneath, his boats; and in the deſcending and aſcending boats each keeping their proper track; and not moving alternately in oppoſite directions, as in the method practiſed at Dungannon and Coalbrook Dale, and as recommended by Mr. Leach and Dr. Anderſon. His boats, he obſerves, may be of a rectangular form, and from 2 to 4 ‡ feet wide. Thoſe of the latter width which he particularly deſcribes, he recommends to be 20 feet long, and 2 feet 10 inches deep; and propoſes

* A Treatiſe on the Improvement of Canal Navigation, exhibiting the numerous advantages to be derived from ſmall Canals. 4to, with 17 plates, 1796.

† They are more properly trucks, viz. wheels between whoſe diameter, and that of their axis, there is little diſparity, and conſequently their friction great; as alſo is their inability to ſurmount any caſual obſtacle.

‡ In the title page he ſays 2 to 5 feet.

them

them to carry four tons each. He ſays they may be " compoſed of 3 inch " deal, bolted and ſcrewed in the uſual mode, and ſtayed at the corners, " with two knees or ribs inſide, exactly above the wheels, and about 5 " feet from the ends, which will leave 10 feet in the centre." Under the boat's bottom, he propoſes two pair of wheels of from 6 to 10 inches diameter; the axle and pair of wheels to be of one piece, and turn on braſs or iron collars. Each pair of wheels are to tread only two feet, ſo as to be perfectly clear of the ſides of the Canal: and, to prevent any impediment from their axle-trees, they are to be caſed over with thin plank, forming a falſe bottom from one axis to the other. A boat ſuch as deſcribed will (excluſive of the frame under the bottom, which I ſhall admit to float the wheels) be equal to a ſolid maſs of fir timber of the length and width of the boat, and 8 inches in depth; and, allowing for the iron work, will draw at leaſt 6 inches when light, excluſive of the wheels; and with 4 tons bare weight (allowing in round numbers 36 cubic feet of water to be a ton) will draw 2 feet $3\frac{1}{2}$ inches.

Theſe boats then with wheels ſix inches below their bottoms, will draw 2 feet 9 inches water: and as there ſhould always be 2 or 3 inches to ſpare, their draught will be too great for * fords; therefore bridges cannot be diſpenſed with. He propoſes, very properly, that the canal ſhould be every where wide enough for boats to paſs each other; which, of courſe, will be 3 or 4 feet more than their joint width of bottom; as, otherwiſe, the ſides of the Canal would be cut down by their ſharp angles; which, even then, cannot be effectually avoided.

* The fords ſhould be all paved; and if the boats in going over them ſhould touch, their wheels would help them on; but it would not be adviſeable, as one horſe ſhould draw ſeveral boats, to ſubmit to that inconvenience.

A ſix-inch wheel I look upon as of ar too ſmall a diameter; but as, by ſpiking a piece of board immediately over the wheels, they may be let nearly or quite through the bottom, and a larger diameter be admitted; I ſhall only add 6 inches below the bottom, which ſpace is requiſite to prevent the neceſſary curveture of the extremities of the railway touching the boat.

The

The depth below the water line cannot, with propriety, be lefs than 3 feet 6 inches, to make proper allowance for filting up: and 9 feet width of bottom, is the leaft it can be, to admit of the free paffage of thefe upright fided boats.

Thefe dimenfions are below what Mr. Fulton has informed me he propofed: and I have purpofely affumed them to fhew that the comparifon, in the next chapter, is not calculated to depreciate the fyftem he has brought forward.

CHAP.

CHAP. II.

On the comparative Expence of forming narrow Canals with inclined Planes, and wide Canals with Locks; ſtating alſo their reſpective Advantages, and comparing the Conſumption of Water by Mr. Fulton's Plan, with what is requiſite for Locks.

AS the great diſparity of expence is a leading argument, with Mr. Fulton, againſt the Lock Syſtem of Navigation; I ſhall, before I proceed, ſhew how far that ſyſtem ought to be followed, or rejected, for the one he has recommended; and endeavour to prove, that in general inſtances, the diſparity of expence is not nearly ſo great as he has ſtated. For this purpoſe, I will compare his plan with a navigation for 50 to 60 ton boats, of 60 or 70 feet length, 14 feet width, and 4 feet 6 or 4 feet 9 inches draught of water; a ſuitable Canal for which would be of 24 feet width of bottom, and 6 feet depth of water; which would afford room, every where, for two boats to paſs, as their ſection would not be angular, but curved. The diagrams 1, 2, 3, 4, and 1, 5, 6, 7, *figure* I. *plate* I. (admitting the ſlopes to be what they moſt generally are, viz. 18 inches baſe for every foot in height), will ſhew the profile of each Canal, at what is termed level cutting, viz. where the level of the ground is equal to the ſurface of the water.

The ſecond comparative diagrams, viz. *a*, *b*, *c*, 2, 3, *d*, *e*, *f*, and *a*, *b*, *c*, 5, 6, *g*, *h*, *k*, ſhew what they will be at 5 feet extraordinary ſinking; allowing, at 2 feet above the water, 9 feet offset on the towing path ſide; and a berm of 3 feet on the other, to prevent earth tumbling into the Canal. The diagrams 8, 9 and 8, 10 in the ſame figure, ſhew 10 feet extra ſinking.

Theſe diagrams will be more or leſs near the truth, according to the tenacity of the ſoil, and other circumſtances; but I have taken them at the

the general run of the foils of the navigations of this country; which, although when firft cut, they will ftand fteeper, will generally crumble down to 16 or 18 inches bafe, to a foot in height; at which flope, loofe foil will ftand when not agitated by water.

The fucceeding comparative diagrams, in *figure* 2, *plate* I, fhew the embankments of one fide of each Canal, where the furface of the ground is $2\frac{1}{4}$ feet, 6 feet, and 10 feet under the furface of the water. The line *a b* is the middle of the fmall canal, and *d e* that of the greater, allowing them to continue of the fame width as where their channels have to be excavated. They are generally wider in embankment, particularly in thofe of fmall height; which, fo far, would operate againft the fmall canals.

Thefe feven pofitions of comparifon are what will commonly occur, exclufive of greater difficulties (which will ftill more equalize the fyftems) and for that caufe I have affumed them.

At a given diftance from the fummits of mountains towards the low grounds of the valleys, a regular tract may be found, where, without much curvature, a line of level cutting may be uninterruptedly carried.

The falls, in thefe countries, are confequently great; and minerals the almoft fole articles of carriage.

The fides of the mountains are alfo frequently too fteep, and the foil too fhallow, to admit of wide Canals without great expence; therefore, under thefe predicaments, inclined planes and fmall boats are moft eligible: but, on the general elevations through which lines of Canal run, the country is often croffed tranfverfely to the courfe of the fmaller rivers; and the furface of the ground neceffarily undulates; fo that no continued line of level finking can be obtained, without immenfe * circuity, viz. without curving

* According to Mr. Leach's account (in Page 47, of the 2d edition of his works) the diftance from Bude Haven, in the Briftol Channel, to the navigable part of the Tamer falling into the Englifh Channel, is no more than 28 miles in a direct line: but, by the courfe neceffary to be taken in the feveral intervening valleys in order to preferve the level, the line was extended to upwards of 80 miles.

to

to the brow of every ſwelling point of land, and returning up every vale, until the proper level be regained; which, in itſelf, is ſo obviouſly abſurd, that no further reaſoning is requiſite to ſhew the neceſſity of frequently incurring a fluctuation of more than 10 feet above and below the line. I ſpeak not of the vales of great rivers, which I allow may be paſſed by inclined planes, deſcending to the valley and riſing on the oppoſite ſide: but were this to be done on every ravine that is to be paſſed, the inconvenience would be great indeed: and, therefore, many embankments muſt occur far beyond what I have ſtated; and I ſhall now proceed to their comparative examination.

	4 *Ton Canal.*	60 *Ton Canal.*
In the firſt ſtatement, or level cutting, the comparative ſections and conſequently the quantity of earth are,	50	198
At the depth of 5 feet extra ſinking, - - -	221	482
At 10 feet do. - - - - -	491	864
Surface of ground 2 feet 6 inches under water line, -	107	107
Do. * 6 feet do. - - - -	287	287
Do. 10 feet do. - - - -	577	583

From whence it follows, that under the firſt predicament of level cutting, the quantity of the ſmall Canal is ſcarcely more than † one fourth of the greater: that, in the ſecond inſtance, it advances to more than four ninths; and, in the third, to nearly four ſevenths; ſtill approaching nearer as the cutting becomes deeper. And as the embankment, when even ſo trivial as 2 feet 6 inches, and thence downwards to above 6 feet, is equal in

* The banks are eſtimated at only 10 feet width each; and one foot mean height above the ſurface of the water; and without allowance for ſubſidence.

† If no puddling to keep in the water were requiſite the expence would be leſs than a quarter; becauſe the whole might be caſt out: but as the puddling (which in the leſſer Canal would be twice as coſtly as the excavation) would be nearly as the ſurface of the ſides and bottom, the diſparity would be ſo far reduced in what may require puddling, that the general proportion of expence may ſtand as the quantity of excavation, or even higher.

both

both Canals; at 10 feet nearly the same; and, afterwards, not essentially in favour of the small ones, until the embankments become very high: it may fairly be concluded, that in the common run of navigable lines, such as described, the expence of cutting the Canal for four-ton boats would be half that of a Canal for 50 or 60 tons.

2d. The expence of fencing and gravelling the track-way will be the same in both.

3d. The next expence I shall consider is the land, the quantity of which will be precisely the same as to the towing paths, the slopes of the banks above water, and the outward slope of the embankments; the sole saving being in the reduction of the water line: and taking the average in a favourable statement for the small canal, the land required will be three fifths of the larger.

4th. Brooks must be passed under the * small canal in common with the large ones; and as the expence of the ends of the culverts would be equal in both cases; the only saving, unless some excavation under low embankments, would be in their difference of length, which, in the higher embankments, would be only the difference of the width of water, viz. 22½ feet; and, under low embankments, where the culvert would require to be as high as the depth of water in the shallow Canal would admit, the saving in length would be 30 feet, viz. the difference of width of water added to the reduction of the width of the embankment on the level of the culvert. If, in this instance, the culvert under the deep Canal be either syphon formed, or raised at the upstream end, the disparity of length would be less; but the difference of excavation in favour of the small Canal has

* Dr. Anderson proposes to save the expence of most of the culverts, by bringing the lesser rivulets into his small Canals, and passing them over paved overflows opposite to the inlets; but this scheme, besides inevitably filling his Canal with sand and gravel, would in great floods render it impassable, and overflow the regular height of the banks; and also would never be agreed to by those possessing mill property on the streams into which these brooks flow.

alſo to be taken into account. The ſaving, upon an average, will be nearly one third; and, aſſuming it as ſuch, the expence of culverts under the ſmall Canal will be two-thirds of what would be required under the other.

5th. The next point of conſideration is bridges, which, in common with the others, will require towing paths; and, therefore, ought not to be leſs than 10 feet ſpan, and muſt be of ſufficient height to let the horſes paſs under. A boat of 14 feet beam (viz. 10 feet wider than the ſmall ones) will require a bridge of 20 or 21 feet ſpan. The wing walls, and towing paths, will be common to them both; and the foundation and parapets being taken into account, the bridge will, in the ſmaller inſtance, average about four-fifths of the greater; but as a reduction in height will diminiſh the thickneſs of the walls, the whole expence may come to about one half.

6th. In the general run of countries, ſuch as I have deſcribed, the fall is often ſo extremely progreſſive that, even where water is in ſuch abundance as to induce the parties to build double locks wherever the fall admits, they are frequently neceſſitated to build locks of moderate fall, to avoid a long embankment on the one hand, and a continuation of deep cutting on the other. Under this predicament, they would be equally conſtrained to have inclined planes of ſmall fall, with all the apparatus that would be requiſite for great ones. The ſaving, therefore, could not be more than one third; but, on an * average, I ſuppoſe it would be fully one half; and under theſe premiſes, and the ſuppoſition of the ſame average of

* In ſituations properly circumſtanced for ſmall Canals and inclined planes of great fall, I will admit the diſparity to be four to one in favour of the former, as to aſcent and deſcent. I am friendly to the uſe, and only controvert the abuſe of the ſyſtem.

proportionate

proportionate expence in paſſing valleys, I will now proceed to a ſummary of the general compariſon.

		General proportion.	
	Fractional proportion.	*4 Ton Canal.*	*60 Ton Canal.*
1ſt. Cutting, viz. Sinking and embanking, -	$\frac{1}{2}$	1	2
2d. Fencing and gravelling the trackways, -	0	1	1
3d. Land, - - - -	$\frac{3}{5}$	3	5
4th. Culverts, &c. - - -	$\frac{2}{3}$	2	3
5th. Bridges, - - -	$\frac{1}{2}$	1	2
6th. Deſcent and aſcent, - - -	$\frac{1}{2}$	1	2

From theſe deductions * it follows the ſavings in ſuch inſtances as I have premiſed, will be very conſiderably leſs than one half by adopting the Navigation, deſcribed by Mr. Fulton, for four-ton boats, in place of thoſe of 60 tons. I will call the ſaving two-fifths; and then proceed to exámine what muſt be ſacrificed for that acquiſition.

1ſt. The carriage, in a very conſiderable degree, of all articles that will take damage by being wet †: becauſe the narrow boats of 20 feet length, reſting

* In tunnels through hills the ſaving would generally be about three-fourths; but this is not taken into account, becauſe, where any conſiderable portion of a Navigation muſt be ſubterraneous, that circumſtance will demand ſome reduction of width, accordant with the extent of it, the difficulty of execution, and the objects of purſuit.

† Under this deſcription muſt be included grain, the chief produce of the land; the eaſier diſpoſal of which forms the general inducement for landed proprietors to encourage Canals. From this cauſe, and the creation of demand for internal products of the earth that might otherwiſe lie dormant, and from the conveyance of lime for manure to parts that could not otherwiſe eaſily obtain it, the landed intereſt receives more benefit from internal Navigation than the adventurers who incur the charge of the works, and run the riſque of their failure of reaſonable ſucceſs; which although dubious to the latter, can never be ſo to the land-owner; as, by means of Canals, diſtant and unfavourable ſituations come under

 regular

resting on two transverse lines over the wheels, would, with heavy cargoes, be very liable to strain, so as to become leaky: and admitting they had a raised ceiling, which they must have for the carriage of dry goods, the water from the change of position of the boat, on ascending and descending the inclined planes, will run to the extremities, and be dashed about so as to damage the goods; unless the ceiling were raised at the ends, so as greatly to reduce the stowage of the boats.

2d. When boats, on the different levels, are committed to the care of different men, it will be impossible to fix under whose charge the damage happened, unless it became a rule to examine the boats at every place of change of men, which would be attended with too much delay.

3d. From the same causes, and the boats having no decks, it will be difficult to prevent pilferage of liquors and small articles.

4th. Whenever the wind blew strong, the boats would be liable to take in water over their gunwales, notwithstanding their tarpaulins, unless they were battoned and nailed down as in ships hatchways: and, in every cross reach, the string of boats would blow ashore without a man to every boat to keep them off, which would be far too expensive. At Ketley, they had rails projecting into the Canal, on the convex points, to keep the boats in their regular course, which enabled them to go forward in moderate weather; but to navigate, in any strength of wind, they would, if even they had rails all the way, require the aid of men to enable boats that were going opposite ways to pass each other. Or, otherwise, they must track their boats with such speed as to keep them off the shore, and consequently have very few to a horse.

regular cultivation, and advance of rents far beyond what could otherwise be given. The frequent opposition from that quarter, and the support that such opposition meets with, clearly shew, that gentlemen of landed interest do not in general see this advantage in the light in which I have described it: the same opposition, I am informed, existed on the first introduction of turnpike roads, the value of which has now been sufficiently experienced; and the superior advantages of Canals cannot fail being soon as generally known.

In

In moderate weather, it would be difficult for a horſe to drag a line of them 200 feet long, viz. 10 boats as propoſed by Mr. Fulton. The ſection of water oppoſed is but ſmall; but the form of the ends of the veſſels is that which gives the greateſt reſiſtance; and they are often repeated, which muſt produce a conſiderable effect, although one veſſel follows in the wake of another. Further cauſes of reſiſtance will ariſe from the line of boats frequently forming a zigzag, and from their vaſt ſurface expoſed to the water. The whole of the effects combined are not reduceable to calculation, and muſt depend on experience.

5th. Packs of hemp and wool, bales of cotton, ſacks of hops, crates of earthen ware and of glaſs, oak bark, bavins, &c. &c. would lie too high, ſo as to overturn the boats, unleſs iron, lead, blocks of tin, or other ponderous articles, were carried at the ſame time; without which, theſe boats would not carry half their tonnage of light goods in any package; the Staffordſhire ſquare-ſectioned boats of ſeven feet width, will ſeldom ſtow, without becoming top heavy, more than two-fifths of the weight they can carry, at a leſs proportionate depth than the boats in queſtion muſt be loaded to, to carry four tons.

In addition to the articles already mentioned, theſe boats cannot carry either long or crooked timber; the former, if of fir, may be floated: but the latter, if of heavy wood, will ſink, and cannot eaſily be managed. Neither would theſe boats be very ſuitable for the conveyance of quick-lime, nor would they carry (becauſe of their ſoon overturning) nearly their tonnage of wheat in ſacks, and ſtill leſs of rye, barley, oats and malt: I, however, do not mean to infer that they will not carry theſe latter articles at all; but only that the quantities will be leſs, nearly in the ratio of their ſpecific gravities; which deficiency in tonnage may, in ſome inſtances, be compenſated by reduction of toll. This width of boat is, however, what cannot be recommended for general purpoſes.

The broad boats of 14 feet will nearly carry their full tonnage of light goods, which circumſtance ariſes from two cauſes: the one is their form (as well as their width) which occaſions their metacentre, or point below which

which the joint weight of boat and cargo may lie without overturning, to be higher than in the other boats *; and the other is, that they are ſunk, when laden, to a much leſs proportion of their width: beſides which, when their draught of water is indefinite (as will further appear from the next chapter) the quantity of light articles that can be carried by boats of different widths, but of ſimilar form and length, will be as the ſquares of their widths; therefore, a boat of four feet width, in place of carrying half as much as a ſimilar one of eight feet, will only carry a fourth, although of the ſame length; and but a ninth of one of twelve feet width.

6th. The tranſhipping of articles removes the reſponſibility; and, as boats are frequently wanted to navigate both canals and rivers, which cannot be done by the ſmall boats, that degree of reſponſibility muſt be loſt, and the charge and delay of tranſhipping be incurred.

7th. The ſaving in point of reduction of Canal dues, would not, in articles of merchandize, be equivalent to the inconveniences deſcribed.

Having now mentioned my objections to the univerſality of the ſyſtem recommended by Mr. Fulton, I ſhall proceed to notice the caſes wherein I think it eligible, the ſteps I think neceſſary to its perfection, and the means of "harmonizing the ſyſtem of internal navigation;" which will not conſiſt in the annihilation of Lock Canals as he has ventured to prognoſticate, but in rendering the modes of conveyance in them all, as far as poſſible, conſonant to each other. Previous to this, I ſhall make ſome obſervations on the conſumption of water. In Locks there is this inconvenience, that, whether the boats aſcend or deſcend, be light or laden, they conſume, on an average, a Lock-full of water; for, although in going downwards, they ſave a quantity equal to the weight of the boat and cargo if laden, or of the boat alone if light, in conſequence of the bulk of the immerſed part

* Canoes, uſed on the American and other rivers, becauſe of the curved form of their tranſverſe ſection, carry their lading higher than ſquare-ſectioned boats of ſimilar width, and are therefore capable of conveying large hogſheads of tobacco, or of other articles, with ſafety.

of

of the boat being expelled from the chamber, on the boat's entering from the upper level; this is perfectly counterbalanced by the reverse taking place in the ascending boats, on their quitting the chamber to enter the upper level; consequently, exclusive of leakage, which in well fitted gates is very inconsiderable, we may estimate a boat to consume a lockful in passing any extent to or from the summit. Wherever water is scarce, it is common not to exceed eight feet falls, and to have no double Locks. The next consideration is the depth of water in the Canal; for the greater the depth, the tonnage, contained in any given width and length of boat, will be the more increased.

I will assume the depth of Canal I have heretofore compared the small ones with, viz. 6 feet, which will allow of boats of upwards of 4 feet 8 inches draught. These boats, when light, need not draw so much as 15 or 16 inches water, which will allow 3 feet 4 inches to be sunk by the cargo. If the boats and locks be proportioned to each other, as in all cases of want of water they ought to be, the area of that portion of their height should be at least equal to three-fourths of the area of an equal height of the Lock; consequently, in this instance, 2 feet 6 inches height of the Lock (viz. three-fourths of 3 feet 4 inches), will be equal to the weight of the cargo. Therefore, in a fall of 8 feet, the consumption of water would only be $3\frac{1}{5}$ times the weight of the articles that would be passed, up or down, in place of the disproportion he * speaks of, viz. 133 tons of water for passing 25 tons of goods, instead of 80 † tons (which, as above stated, should produce that effect).

Where the descending trade does not bring up the ascending, he supposes that, by his own system, the weight of water consumed will be ‡ twice

* Vide Fulton, page 69.

† The above clearly relates to a passage only one way; but, if a boat pass a summit, the consumption of water will be twice as much; unless another boat pass down with the same lockful the former rose with. And if boats pass and repass a summit, laden one way only, the water requisite would be nearly 13 times the weight of the goods conveyed: but these extreme circumstances are never permitted to take place wherever water is scarce.

‡ In some instances much more. Vide Fulton, page 79.

that

that of the tonnage. And every valley he paſſes, by the double inclined plane (deſcribed in chapter xi.) deſcending on one ſide of the valley, and riſing on the other to that or any other level will, of courſe, repeat the preceding conſumption, ſo that the waſte of water may become as conſiderable as by the Lock ſyſtem, particularly if the method invented by Mr. Dubie, in the laſt century, and deſcribed by * Belidor, be put in practice, as may, in ſome few caſes, be eligible, viz. the drawing off the upper half of the height of the Lock into a ſide reſervoir, and the remainder into the lower level; ſo that, in refilling the Lock, the lower half may be filled from the reſervoir, and † half only be drawn from the pond, or level above. Or, nearly the whole water may be ſaved by the Locks deſcribed in the 11th and 12th articles of the preceding chapter.

Mr. Fulton has ſtated ſeven minutes as requiſite in the paſſing a Lock, which in ſome inſtances is the caſe; but, where ſufficient water way is given to the ſluices, and expeditious means of opening them adopted, a large Lock may be filled or emptied in two minutes, and a boat paſſed through (incluſive of the filling) in three minutes, which degree of expedition is requiſite wherever paſſage boats are an object.

* Architect. Hydraul. t. 4, p. 412.

† This may often be eligible in Locks of two or more falls, as a reſervoir may be given to each. The ſubdiviſion of height of a chamber, may be extended to three or more, ſo as to reduce the quantity ſtill further; but it would be counteracted by the increaſe of expence, and the delay in paſſing the Lock: neither will the ſaving be quite in the proportion of the number of the reſervoirs, becauſe of the fluctuation of the level of their ſurface, which will be more or leſs according to their proportionate magnitudes. The method taken by Mr. Dubie, in a Lock of 20 feet fall, on the Canal of Ypres, was to have three diviſions for admiſſion of the water.

CHAP.

CHAP. III.

Cases where the small System of Navigation is eligible---with some Proposals for its Improvement.

THE system of small Canals is particularly eligible in all countries where limestone, coal, iron ore, lead, and other ponderous articles not liable to damage from being wet, or likely to be stolen, are the objects chiefly to be attended to; and where the regular declivity of the country runs transversely to the course of the Canal: which will generally be the case along the sides of mountains, at an elevation above the irregular ground at their feet.

In those situations, the great falls, or inclined planes, may be made at the forks of rivers; so that the upper levels may branch up both the vales, and thus give the most extended communication. A situation suited for those canals will often also be found in countries that are not absolutely mountainous, but where the ground regularly declines towards the vales of large rivers.

Bridges, whether of high roads, or of communication between divided property, form an essential article of expence, and may be considerably avoided in the small system. The only thing militating against it, in the wheel boats, is the great projection of their wheels below the bottom, which renders fords impracticable. The fords ought not to exceed two feet nine inches depth; as, otherwise, hay, sheaves of corn, &c. in common carts, would be liable to get wet. The depth might always be nearly uniform, from the fords being paved, and overflows immediately adjoining, which, to allow for casual fluctuation, might be fixed at two feet six inches above the pavement of the fords: then, in place of communication-bridges, it would only be necessary to form a paved road obliquely down the bank on one side, crossing the Canal in the same direction, and sloping

1ſt. I propoſe their wheels to be 12 or 14 inches diameter, and only to project two inches below the bottom. Theſe wheels muſt, neceſſarily, be ſheltered by the ſides, not only to avoid ſtriking againſt the banks, but that the boats may not entangle with each other.—(*Vide Plate II*).

This purpoſe might have been effected by means more ſimple than ſhewn in the plan, &c. were it not for the neceſſity of attending to the vertical curvature of the railway, which will project upwards, alternately, between the wheels, or towards the ends of the boats. The part of the boat below the wheel's axis, although contracted 6 inches in width, on each ſide, as *fig.* 3, will not only add conſiderably to the burthen, but afford the means of preſerving the cargo from being injured by leakage: becauſe the ceiling of the boat being neceſſarily raiſed above the thwart timbers, and a conſiderable ſpace left between the ceiling and bottom plank.

2d. The increaſed width of the boat from 4 feet to 4 feet 6 inches, will add both to the burthen and ſtability of the boat, without any ſenſible difference of expence in the Canal, as one foot more width, which requires only a vertical ſection of that width, will afford the neceſſary increaſe of ſpace to allow the boats to paſs each other, and the increaſe of excavation of the Canal is comparatively nothing, becauſe the ſides are common to all widths of the ſame depth; from which cauſe, excepting where ſubterraneous navigation is requiſite, there are no ſufficient advantages ariſing from a very limited width; and, even under that predicament, if there be any material length of carriage, either under ground, or ſubſequently, it will be eligible to keep, at leaſt, to the width I have mentioned.

The boats in the Duke of Bridgewater's works at Worſley, where there are ſubterraneous Canals on different levels, are of this width. There are ſome caſes in ſhort ſubterraneous Canals where 4 feet or leſs width of boat may anſwer the purpoſe. It may be frequently ſo with iron, or other ores, and ſometimes with coals, when ſent forward in the ſmall corves or boxes, in which they are brought from the face of the mine; as, in this inſtance, the boat would only be laden to a ſmall depth, and the cargo not lie ſo high as to endanger its overturning.

3d. If

	Feet.	Inches.
3d. If the boats be from 3 to 4 times as long as they are broad, their draught of water, when light, may be -	0	8
Projection of wheels below their bottom -	0	2
Depth to be sunk by their loading - -	1	6
Total	2	4

at which draught I have before stated, they may navigate over the fords without danger of impediment.

Under the above predicaments, every 5 feet 4 inches length of boat will carry a ton; therefore, 4 tons may be carried in one of 21 feet 4 inches length, and 3 tons in one of 16 feet; which latter size, as being less liable to strain when resting on its wheels, and for other causes will, in general, have superior advantages.

In boats laden with coals, lime, iron ore, or other minerals, it will evidently be a great convenience to empty them with equal facility as a waggon; which, particularly in short boats, may be effected in the two following ways: the boats, in both instances, having their ends ceiled, with a slope of about 18 inches base to a foot in height. The Canal (in the first method that I shall describe) should terminate above, and near to, the place of discharge, which, in this instance, I will suppose to be a coal staith. At the end of the Canal there may be a dock just containimg a set of boats (which will be hereafter described) or a gently ascending railway; in the latter case the boat may easily be drawn out, by a horse acting on a two-fold purchase, viz. by a rope attached to a post close to the side of the railway, and above the head of the slope, which rope being passed through a block hooked to the head of the boat, and returning to a horse harnessed to it, upon the railway, will give power sufficient to raise the boat out, in the space of 10 yards; the first part of the ascent being steep, on account of the boat being waterborne.

If a dock be used, the waste of water will be small, as there will be no descent of the boat; and the only difference will be, that the boats will be more easily run forward over the frame-way of the staith. When arrived

at

at any place of discharge (whether upon the staith, or into vessels lying below) the boat will have to run upon a frame suspended on two gudgeons at half its length, a little below the centre of gravity of the loaded, and above that of the light boat; the frame (being so contrived that the boat on taking its position, becomes secured in its place) will then readily be turned up to such * position as will permit the contents of the boat to shoot out, and will, afterwards, be as readily turned back again, from the position of the centre occasioning it to preponderate each way alternately.

Where the coals, or other minerals, are not wanted to be occasionally lodged in a staith, but to be only turned over into larger vessels, on a greater navigation; a method practised in a part of South Wales, with small boats bringing iron ore from a drift out of the mine, may be made use of. It consists in continuing the Canal (which may be a wooden trough) to the place of discharge, and terminating it on a caisson, suspended on a transverse centre. The boat being arrived in its place, the end of the Canal is closed by a stop-gate; and the small quantity of water contained in the caisson, which the boat should as nearly as may be fill, being let out, the case, or frame, with the boat in it, may be turned over as already described.

In the former method (which will be more generally useful) the boats will, occasionally, have to shoot their cargoes, in different places, on a coal staith, or quay, and consequently will have to turn; therefore, boats of 16 feet length, which I have already said will carry 3 tons each, cannot conveniently be made use of; that circumstance may render it eligible, in many instances, to have them shorter, and of less burthen; which, according to the system I shall proceed to lay down, will be attended with no disadvantage of moment.

* The turning of the frame must be limited to the extent of this position, which, with the end slope of the boat's ceiling, already mentioned, will be sufficient at little more than 70° from the plane of the horizon. The sides of the frame should fit close to the boat's gunwale, and rise sufficiently above it, to prevent the matter it contains from running over its sides when rushing out of the boat.

I have

I have already mentioned the extreme difficulty of managing a train of boats, when the wind blows ſtrong; and alſo the great reſiſtance to their paſſage through the water from the form of their ends, as well as the damage done to the banks from the angles of the boats, which principally * ariſes from the corners plowing up the banks. To remedy this, for any great extent, by any thing placed along the banks of the Canal, would be worſe than the diſeaſe; ſome other mode muſt therefore be adopted.

The way, that occurs to me, is to conſtruct and connect the boats, in ſuch a manner as to avoid cutting the banks, and likewiſe enable them to go ſufficiently faſt through the water, ſo as to be capable of ſteering, and not to be driven by the wind on either bank, and, at the ſame time, retain the power of being ſent down the inclined planes without being ſeparated.

Two, three, or more boats, according to their length and the ſuddenneſs of the curvature of the Canal, may be firmly connected, one cloſe behind the other, ſo as to form one boat; and, by having a ſlight overhanging at the end of each, they will, when on their wheels, bend to the convexity of the upper part of the railway, and being faſtened near the gunwale at each angle on either end, there is no impediment to their equally ſuiting the concavity of the lower part. The boats, thus connected, would ſtill oppoſe great reſiſtance to motion; and although, by giving the extreme ones a triangular end (which would be the eaſieſt executed), the reſiſtance would be leſſened nearly as the † ſines of the angles of incidence: yet other in-

* The damage ariſing from the rectangular tranſverſe ſection of boats for inclined planes is conſiderable, and can only be remedied by incurring inconveniences in the conſtruction of the boat; and the capability of its ſuſtaining itſelf on a frame without ſtraining, unleſs uncommon accuracy were attended to, in ſuiting the boats bottoms and their cradles to each other.

† At firſt in a greater ratio, afterwards in a leſs, according to the experiments of Abbé Boſſut.

If one leg of the iſoſceles triangle forming the entrance, or end, of a boat be aſſumed as radius, the reſiſtance would be as the ſquare of the ſines of the angle of incidence; but then the width of the boat would decreaſe or increaſe, as the ſine is to radius; conſequently, in boats of equal width, the reſult would be as the ſine.

conveniences

conveniences would enfue; as the boats would be attended with a great lateral wave, tending to tear town the banks, and a reduction of burthen equal to half the projection of the ends, which muft, of courfe, be counterbalanced by an increafe of length. I therefore recommend the ends of each fet of boats, to be formed like an obtufe pointed gothic arch, as the dotted lines in *fig.* II. *plate* II. where, by only an increafed length of one foot, an equal, or rather fuperior burthen to the fquare ended boats will be obtained; and the refiftance reduced, according to the experiments of Admiral Chapman and Monf. de Rommé, becaufe the half width of the boat is only three fourths of the axes of the curve forming each fide of its end; and, by their experiments, the refiftance is equal (under any proportion of extreme width and fpace from thence to the ftem), whether the fides for that extent form a curved water line, or go ftraight forward to the ftem, and form two fides of a triangle.

According to the experiments tried at Greenland Dock, by the Society for the Improvement of Naval Architecture, the refiftance of a veffel with femicircular ends, moving at the rate of eight feet per fecond, and 11½ times as long as broad, was nearly .78 of that of the fame veffel (or body compofed of logs of timber) with fquare ends. By thefe experiments, and thofe tried at Verfailles by L'Abbé Boffut, the chief advantage is derived from the form of the end moving foremoft: which will hold good in all velocities with which boats can move on Canals; and, as the propofed ends are formed of half fegments of circles, whofe axis, in the line of the keel, is once and a third the greateft ordinate, or half width of the boat, the refiftance fhould, according to the fines of the angles of incidence of equal threads (or minute portions) of the width of the water intercepted, be .901 of the refiftance of a femicircular end, and therefore .702 of that of a fquare * end, according to the experiments quoted, which nearly agrees with the fines † of the angles of incidence on equal and minute portions of width.

* This advantage, in the experiment quoted, would be partly derived from an equal fharpnefs in the after end, which will not operate againft the prefent cafe, as each end of every fet of boats fhould be fimilar for the purpofe of tracking either way.

† According to this theory the refiftance of a femicircular end proportioned to a fquare one is as .7854 to one, becaufe the fum of the natural fines of a quarter of a circle, taken on equal portions of its greateft ordinate, infinitely near, muft obvioufly form its area.

In

In all experiments, the proportionate lengths of the rectilinear part of the bodies to their widths, and in many instances of the latter to their depths immersed, will produce different results: therefore, until the effects of these and of other attendant circumstances be known, and introduced into the formulæ, no theoretic result can be perfectly correct; but will give more or less than any particular experiment, unless where opposite causes counterbalance each other; amongst which, friction on the surface exposed to the water, and the inequalities of that surface, are not the least considerable.

CHAP. IV.

On the Metacentre or Axis of Motion of Veſſels of a uniform Figure throughout their Length, ſhewing by ſeveral Theoretic Inſtances to what Height ſuch Boats may ſafely carry their Cargoes. Alſo on the Means of combining the Navigation of ſmall and great Canals.

AS Canal veſſels, eſpecially the narrow ones, which are principally the ſubject of this Treatiſe, are generally of a uniform figure throughout their length, or axis of motion; except a ſhort ſpace at each end, which, from their great comparative length, conſtitutes an inconſiderable portion of the whole, I ſhall conſider them as ſuch; as it not only ſufficiently approximates the truth, but diveſts the queſtion of the intricacy that would otherwiſe attend it. This ſubject having been treated with great ability by Mr. Atwood *, in the Philoſophical Tranſactions for 1796, I ſhall occaſionally recur to him, for the rules neceſſary for inveſtigating this matter.

In all veſſels there is, at every given depth to which they may be laden, a certain altitude of the centre of gravity, at which the veſſel will be on an equilibrium of indifference whether to remain at reſt, or move a greater or leſſer diſtance round its axis of motion; which axis (in the line of the veſſel's length) is uſually called the Metacentre: conſequently, if the centre of gravity of the veſſel and cargo combined, lie above the metacentre, the veſſel muſt overturn; and, according to the diſtance of the centre of gravity below that point, the greater or leſs will be the ſtability of the veſſel. Its reſiſtance to overturning, if it be of a circular tranſverſe ſection, will be equal to the ſine of the angle of heeling, multiplied into

* The Conſtruction and Analyſis of Geometrical Proportions determining the Poſition aſſumed by Homogeneal Bodies which float freely, and at reſt on a Fluid's Surface; alſo determining the Stability of Ships, and of other Floating Bodies: by George Atwood, Eſq. F. R. S.

the

the diſtance between the centre of gravity and the metacentre * multiplied by the weight of the veſſel and cargo, which muſt, conſequently, increaſe until it arrive at its maximum at 90°.

Alſo, in veſſels of this form, the metacentre continues at the ſame height above its bottom, at whatever depth the veſſel may float; but, in polygons, the caſe is varied, and in the rectangular form very conſiderably.

It is obvious, that no floating body can be naturally at reſt, unleſs its centre of gravity be ſupported vertically by the centre of gravity of the fluid diſplaced; or, in other words, of the part immerſed.

In a parellelopiped, or ſquare beam of timber (ſuppoſed to be homogeneous), its centre of gravity will clearly be where its diagonals interſect (vide *plate* I. *fig*. III. and IV.), and if its tranverſe ſection be equilateral, it would, when floating on the water, obviouſly reſt on an equable ſupport, either on one ſide, or with one angle downwards; but yet, it will not remain indifferently in either poſition; for, according to circumſtances, one of theſe poſitions would be what Mr. Atwood calls, " the equilibrium of ſtability, in which the ſolid floats, permanently, in a given poſition;" and the other would be " the equilibrium of inſtability, in which the ſolid, although its centre of gravity and that of the part immerſed are in the ſame verticle line, ſpontaneouſly overſets, unleſs ſuſtained by external force."

When veſſels of a rectangular ſection are uſed in Canals, they are neceſſarily to float on one ſide, or face of the ſquare; but Mr. Atwood has clearly demonſtrated, that in many inſtances they have, when the centre of gravity is in the centre of the ſquare, a tendency to overturn and float on their angles; which ſhews, that under theſe predicaments, Mr. Fulton's boats of four feet width, could not carry their mean weight of boat and cargo ſo high as two feet from the outſide of their bottoms; even without

* When the tranſverſe ſection is a portion of a circle, the metacentre muſt obviouſly be in the centre of that circle, becauſe, a cylinder of homogeneous matter, floating on its ſide, would reſt indifferently with any part upwards.

any allowance for the requiſite reſiſtance, they ſhould be capable of making to the weight of a man ſtepping on one ſide.

The following are, according to Mr. Atwood, the equilibria of ſtability of a ſquare parallelopiped, whoſe centre of gravity is in the centre of the ſquare, the full depth or one ſide of the ſquare being unity.

	Poſition of Body immerſed.	*Poſition in which it would float permanently.*
1ſt.	0 to .211 and from .789 to 1	With a flat ſurface horizontal.
2d.	.211 to .25 - -	The flat ſurface inclining progreſſively on ſundry angles increaſing to 26° 34′ when correſponding with .25, at which time the ſurface of the fluid will be coincident with one of the angles.
3d.	.25 to .2813, *viz.* $\frac{8}{32}$ to $\frac{9}{32}$ and from .71877 to .75, *viz.* $\frac{23}{32}$ to $\frac{24}{32}$. - -	With the diagonal lines in various angles with the vertical, until it becomes upright at $\frac{9}{32}$ in aſcending from $\frac{8}{32}$, and at $\frac{23}{32}$ in deſcending from $\frac{24}{32}$, at which, and $\frac{8}{32}$, the angles are 18° 26′.
4th.	From .2813 to .71877, *viz.* from $\frac{9}{32}$ to $\frac{23}{32}$, - -	With the diagonal line vertical.

The laſt mentioned depths obviouſly include all the proportions at which narrow boats could conveniently ſwim; therefore, they will be the leſs able to carry their burthens at any reaſonable height.

Theſe different poſitions ariſe from two cauſes; the one is, the natural tendency that the centre of gravity of the whole maſs has to become as low as poſſible: and the other, the tendency which the centre of gravity of the part

part immerſed has to become as high as poſſible; which, conſequently, increaſes the width of the line of flotation, or the ſupport on the water's edge.

I have already ſhewn *, that Mr. Fulton's boats of four feet width, will, with the lading he mentions of four tons in 20 feet length, draw two feet $3\frac{1}{2}$ inches water; and the boat itſelf, without the wheels, which are of no moment in this inveſtigation, would draw ſix inches.

As the depth the boat would draw laden, bears the ſame proportion to the width or ſide of the ſquare, as .5729 to 1. it falls under the 4th, or laſt predicament mentioned in the preceding table; and would naturally overturn if the centre of gravity were as high as the point of interſection of the ſquare, viz. two feet from the bottom. With iron-ore, limeſtone, and other minerals, coals excepted, there can be no doubt of its carrying its cargo ſufficiently below the metacentre, or overturning point; and, as coals are eſſential to this ſpecies of Navigation, I now proceed to inveſtigate how far it will carry the quantity eſtimated.

Coals, although ſpecifically heavier than water in general, more than one-fourth, yet, when broken, as uſually ſent from the mines, a ton weight occupies a ſpace of nearly 50 † cubic feet; conſequently, as 20 feet length of boat is to carry four tons, or 200 cubic feet, it follows, that each foot length muſt require a ſection of 10 feet, which, divided by four feet, the outſide width, leaves two feet ſix inches; to which we have to add eight inches ‡ for the proportionate quantity of matter the boat is compoſed of; and the whole height will be three feet two inches: the centre of gravity of

* Vide Page 12.

† When the ſleck, or ſmall of the coals fill up the vacuities of the large pieces, leſs than 45 cubic feet will weigh a ton; but it would be unſafe to calculate on this extreme.

‡ Vide Page 12.

which will be one foot feven inches, admitting the boat itfelf and the cargo to be of equal fpecific weight *.

Another circumftance is, that unlefs the centre of gravity lie fufficiently low, boats of this form and depth, inftead of progreffively increafing their refiftance as they heel, or incline to one fide, will at fome given point diminifh it. We have, however, only now to confider, how far a Canal boat can be admitted with fafety to heel, which I conceive to be about one-tenth of its width (= 5° 44′ 21″), which I fhall affume as a datum; and proceed, according to the method laid down by Mr. Atwood, to examine how high the metacentre would be under this giving inclination; and what weight the boat would bear upon its gunwale, with its centre of gravity at the height of one foot feven inches from its bottom.

Plate I. *figure* V. A B C D fhews the fection of the boat defcribed; which is bifected by the line *x* 6. *w v* is the line of flotation, or water-line when upright, and drawing 2 feet $3\frac{1}{2}$ inches: *c b* the water-line when inclined 5° 44′ 21″: *g* the centre of gravity of boat and cargo at one foot feven inches above the bottom.

The centre of gravity of the part immerfed in water, when the boat's bottom is horizontal, is clearly at the croffing of the diagonal lines *w* C and *v* B, viz. at *e*, and whenever the boat heels, it muft turn on the point *x* †, which is the middle of the line of flotation; and on immerfing the triangle *b x v*, it muft raife a fimilar triangle *w x c* out of the water. Let *a* reprefent the centre ‡ of gravity of the latter of thefe triangles, and *d* that of

* According to the premifes affumed, the fpecific gravity of the boat is to that of the cargo, as 48 to 50, confequently, fufficiently near the fame. This fmall difference will be more than counterbalanced by the cargo being higher in the middle than at the fides; which, according to the height given, are but two feet ten, which is four inches fhort of the eftimated prifmatic height,

† Any effect in removing the centre of gravity arifing from the caufe that may occafion the heeling, not being taken into account as too inconfiderable.

‡ The pofition of which will be two-thirds of the diftance from *x* along a line, bifecting the face *w c*, viz. two-thirds of *x r*.

the

the other; then the diſtance between theſe points (which taken horizontally, may in all ſmall angles be aſſumed as $\frac{1}{7}$ of the width of the boat) will be the extent which the ſupporting power of the triangle has moved; therefore, the centre of gravity immerſed will be removed horizontally from *a*, ſuch part of (32 inches) the horizontal diſtance between *a* and *d*, as the quantity of the triangle is to the whole bulk immerſed, viz. as .603 is to 27.5; or, as one fourth of the ſpace *b v* is to the ſpace *v* C, which in the preſent inſtance amounts to .7017 inches, and is expreſſed by the line *l k*.—If from *k* a vertical line be drawn, it will at *m*, where it interſects the line *x* 6 (biſecting the boat) ſhew the height at which the equilibrium of indifference will be, under the given inclination, which, in this inſtance, will be at 7.017 inches above *e*, or the half draught of the boat; and conſequently, 20.767 above * the bottom, viz. only 1.767 inches above what has been ſtated as the centre of gravity of the boat and cargo; therefore, the ſole power that the boat has to right itſelf, is the ſhort ſpace that *g* lies withinſide of the vertical line from the centre of ſupport *k*; which, at the given angle of inclination, is only one-tenth of the ſpace *m g*, viz. .1767 inches; on which the whole weight of the boat and cargo is, as it were, ſuſpended from that length of arm projecting from the metacentre *m*, viz. on *o m*, which is capable of ſuſtaining a weight upon the gunwale D inverſely to the length *m n*=25.203 inches. The diſproportion between theſe is 142.6 to 1. and as the weight of the boat and cargo is 102 cwt. the power capable of giving the inclination 5° 44′ 21″ (the vertical depreſſure of one tenth of the width of the boat) is only .715 cwt. or leſs than half the weight of a man; conſequently, Mr. Fulton's and Dr. Anderſon's boats are not ſuited to carry coals to the extent mentioned; and if not ſuited for coals to that extent, it is ſelf-evident they are not ſuited for light goods, for grain † or malt, or even for timber and deals.

* Not vertically, but in the biſecting line *x b*, which is referred to throughout; the boat, as before ſtated, drawing 2 feet 3 1-half inches.

† The ſpecific gravity of wheat in bulk is nearly that of coals, or from 46 to 50 cubic feet to a ton; but in bags (as it muſt be in thoſe boats) it will occupy more ſpace; the other ſpecies of grain are lighter; oats are particularly ſo, and malt is under the ſame predicament.

It

It muſt alſo further be conſidered, that no articles, capable of damage from * water, could be ſuffered to reſt on the floor of theſe boats; from all which it follows, that ſuch boats as I have recommended of 4 feet 6 inches width, are of the leaſt breadth that a Canal for any general purpoſes, ſhould be calculated for, in any ſituation; and, that the raiſed ceiling, in theſe boats, is neceſſary to afford a receptacle for leakage, or other water.

It alſo clearly follows, from theſe premiſes, that boats deſigned to diſcharge their cargoes with ſloped ends for that purpoſe, muſt be of a ſtill greater width; becauſe, carrying their cargoes higher:—That width, without entering into calculation, I would propoſe to be five feet, and the boats to be made proportionably ſhorter; in which caſe, a greater number might be fixed together, to form what I ſhall call a conjoined-boat; either two or four of which, according to circumſtances, may be tracked by one horſe. If the Canal be remarkably ſtraight, a greater number may be conjoined; and then only two ſuch boats be drawn by one horſe attached to a chock, or ſhort maſt, ſtanding about one-third of the diſtance from ſtem to ſtern, of ſuch conjoined boat as may go foremoſt: to the ſtern of this, the ſtem of the ſecond conjunction of boats being faſtened, a boy may ſteer the whole by means of a pole fixed like a flat-lying bowſprit, to the headmoſt of the ſecond ſet, which will ſerve as a tiller to ſteer the preceding one, the latter acting as a rudder †.

But ſhould the Canal not admit of a great length of boat, then, two ſets, as above deſcribed, may be drawn by one horſe; theſe two ſets being connected not by their ends, which would prevent their being well ſteered; but by a line communicating between two ſhort maſts, one in the latter conjoined boat of the firſt ſet, and the other in the leading one of the ſecond ſet (in the ſame poſition as the maſt in the firſt conjoined boat), which will give room for the ſecond ſet of boats to be ſteered as well as the firſt. In the narrow boats deſcribed by Mr. Fulton, he does not ſeem

* Quick-lime is of courſe excluded.

† This method is practiſed in Cambridgeſhire and Lincolnſhire.

to

these boats * thus joined, will be liable to accident from the shock of the great boats, as well as much inconvenience from the agitation of a wide and deep † Canal, and also, that the boats would be very liable to become leaky if they have far to travel on land, either from coal mines to the Canal, or from the Canal to any particular place of consumption: therefore, I conceive that in some instances, particularly in the conveyance of minerals, it will be better to have boats of great length, so constructed, as to have a double railway upon them, and to carry two parallel ranges of waggons; a plan nearly similar has long since been talked of; but, excepting on a small scale as to magnitude of waggon, has, I believe, never been carried into effect, from the following causes, viz. the difficulty of getting the waggons in and out; the danger of straining the boats in performing that operation, and the risk of their being overset in high winds, or from other causes.

The two first objections I propose to remedy, by having a dock at the place of loading and unloading, in which the boats should be laid aground; which may be done with very little loss of water, as they should be uniform in their dimensions, flat bottomed ‡, and nearly filling the dock; the bottom of which should be so high as just to admit the laden boat to float over it. The boats being always laden and unladen in a dry dock, it

* If the boats be so large as to go unconjoined, or with only one junction, which may be done on the plan of carriages under the boats; then little inconvenience or hazard will arise from navigating the large Canals. But even in the plan of moving on carriages, the boats are so shook in moving up and down the inclined planes as to become leaky: to remedy which, I would propose that the carriages, where the boats are large, should move on eight wheels, four on each side, and resting on two axes passing through the middle of parallel bars connecting each pair of wheels; of course, the railway would be less liable to injury, and the shock from impediments would be reduced. The latter may be nearly obviated by any simple contrivance to sweep the rails, which may project from the carriage and precede the wheels.

† In shallow Canals, the waves cannot rise so high as in deep ones, or be so far asunder.

‡ Excepting a deep keel to keep them from driving to leeward; to receive which, there must be a groove in the floor of the dock.

follows,

follows, that they may have leaves at their ends to let down to any requisite depth; which, when raised up and secured, may be kept tight by the pressure of the water:—the sustaining platform may, therefore, be on the ceiling of the boats, which may be raised by deep floor timbers, so as to support the boats sides, and raise the ceiling * above the light mark, both for the purpose of preventing the boats sinking from the leakage of the leaves, when not in use; and to avoid unnecessary descent and ascent for the waggons to and from the docks, the railways at the end of which, should coincide with those on the platform of the boats.

The transverse section of these boats I propose to be a portion of a polygon, as carrying the metacentre higher than a square, and as being less liable to cut down the sides of the Canal.

Waggons of seven feet six inches outside length, six feet outside width at top, and four feet depth, with their sides and ends contracted towards their bottoms, contain a measure (inclusive of the heap at top) of 135 cube feet, or a Newcastle chalder † of coals, which should weigh 53 cwt.; and rating the waggon and wheels at 15 cwt. ‡, each laden waggon will then be 3.4 tons; consequently, 16 waggons, which will occupy a space of at least 60 feet length and 12 feet width, will weigh 54.4 tons. The boat for this purpose, I propose to have sloping ends, so far contracted as just to admit the passage of the waggons, and to be of 64 feet average length, 11 feet width of bottom, 14 feet on the gunwale, and 4 feet height from the bottom of the boat, to the gunwale, as by the section in *Figure* I. *Plate* III.

* Which should be caulked and made tight.

† I shall form my deductions from waggons of this measure, as being the standard of the great coal country; and equally capable of being reduced to other measures, as any other proportion I might have assumed.

‡ The waggons with heavy wheels of upwards of three feet diameter, weigh above a ton, but may be reduced to the weight stated, or less.

The light draught of the boat may be leſs than 10 inches, but I will aſſume it to be brought to that depth by ballaſt between the timbers:—the breadth, on the water's edge, will then be 11 feet 7 ½ inches, and the ſection immerſed will be 9.427 ſuperficial feet. The cargo as afore-mentioned will be 54.4 tons, which multiplied by 36, the cube feet of water in a ton, and divided by 64, the length in feet of the boat will give 30.6* feet for the ſection the boat has to be depreſſed, which will require an increaſed draught of nearly 2 feet 4¾ inches, or in all 3 feet 2¾ inches, but ſay 3 feet 3 inches.

Admitting the pyramidal heap of coals on the top of the waggon to be equal to an additional height of four inches on the width of its baſe *a b*, the centre of gravity of the middle part of the waggon (of three feet baſe) allowing the top and bottom to be of equal length †, will be at two feet two inches; and by the two triangular priſms (each of 18 inches baſe), it will be moved nearly 3 inches higher, viz. to 2 feet 5 inches above its bottom, which will be about 3 inches above the centre of its wheels; and calling the wheels 2 feet diameter, the centre of gravity will be raiſed 3 feet 8 inches above the ſupporting rail; which, according to the plan, being 1 foot 5 inches above the boat's bottom, makes the elevation of the centre of gravity of the lading to be at 4 feet 1 inch. The centre of gravity of the boat will depend on the proportionate timbering of its bottom and ſides, and the iron or ſtone ballaſt it may have in to ſink it to 10 inches; and if I

* Let s expreſs the ſection to be immerſed, viz. 30.6 ſup. feet.

$3\,a$ = the width of light flotation, viz. 11.625 feet.

x = the increaſed depth ſought.

Then, as the boats ſides overhang each of them $\frac{3}{8}$ of their height, the equation will ſtand thus. $3\,a\,x + \frac{3\,x^2}{8} = s$. and the reſult will be $x = \sqrt{\frac{8}{3}\,s + 16\,a\,a} - 4\,a = 2.405$.

† They generally are not ſo, but were I to make any other calculation, it would only be on a particular inſtance, and the weight and poſition of the wheels muſt afterwards have to be accounted for: I therefore, ſhall calculate as above, and leave the wheels and axletrees as a counterbalance for the deficiency of the length of bottom, which they will in general be fully equal to.

aſſume

aſſume it at 18 inches from the bottom, it will be more than ſufficiently high. The mean centre of gravity will conſequently lie between 18 and 49 inches, in the inverſe proportion between 9.427 and 30.6, (the proportionate magnitudes of boat and cargo), which will fix it at 41.55 inches. The centre of gravity of the bulk immerſed will be ſo much above the half draught of water, 19.5, as the two triangles *w p* B and *v q* C. *(Plate* III. *Fig.* I.) whoſe centre of gravity is at the height of 26 inches, (viz. $\frac{2}{3}$ of the draught of water) will, in their ratio to the whole bulk raiſe the common centre, viz. as 132 + $\frac{3}{8}$ of 39 : .6.5 : : $\frac{3}{8}$ of 39 :, .648 *, which, added to 19.5, will give 20.148 inches for the mean centre of gravity of the part immerſed. I ſhall in this boat, the ſame as in the preceding one, admit the utmoſt extent of heeling to be 5° 44′ 21″; but the mode of finding the reſult, will be ſomewhat more complicated than in the former operation, becauſe of the diſſimilarity of the triangles formed by the interſection of the two lines of flotation, and the conſequent inſtability of the point of interſection, which, in veſſels of parallel ſided ſection at the water's edge, throughout the extent of heeling, remain uniformly the ſame.

The deviation from the preceding rules, will eaſily be explained by having recourſe to the diagram *Fig.* III. *Plate* III. in which A B E *b* is the tranſverſe ſection of a veſſel with ſtreight overhanging ſides; and *q* is the point of interſection where the ſides would meet, if prolonged downwards.—*x q* is a line biſecting the angle of junction of the boats ſides: and *w v*, is the line of flotation at right angles with *x q*, when the boat is, of courſe, upright.—*c b* is a line parallel to the line of flotation, on the boat, having heeled any given quantity equal to the ∠ *b x v*. This line paſſes through the middle of the level line of flotation, but cannot be the true poſition of the inclined line; becauſe the quantity of water diſplaced on the ſide heeled towards, and left unoccupied on the other, muſt of neceſſity be equal; and the triangle *b v x*, is obviouſly larger than the triangle *w x c*, :—

* Viz. As the width of the boats bottom + the overhanging of one ſide on the line of flotation, is to the difference between the two centres of gravity (viz. 26.—19.5) ſo is the value of the two triangles (which, as they are equal, is expreſſed by the baſe of one of them) to the reſult.

therefore,

therefore, the real line of flotation will be moved so far downwards, towards v, (say to C H) as to equalize the two triangles, w X C, and H X v.—To find the precise position of this line we have the following data—The triangle, C q H must be equal in area to the triangle, $w\,q\,v$, because the triangle, H X v, is equal to the triangle, w X C,: and the $\angle$ A $q\,p$ being common to both the great triangles in question, the rectangle C $q \times q$ H must be equal to $w\,q \times q\,v$; viz. to $\overline{w\,q}|^2$ as both these lines are equal. These circumstances, combined with all the angles being given, lead to the following operation.

Let $w\,p$ be drawn parallel to the inclined line of flotation; on which line $w\,p$, let fall the perpendicular $v\,s$, the value of which will be the sine of the angle of heeling, the level line of flotation being radius:—$w\,s$ will be the sine complement of that angle. The angle $s\,v\,p$ is equal to the angle of overhanging of the boats side + the angle of heeling (viz.$= \angle\, x\,q\,v + \angle\, s\,w\,v$) and $v\,s$ being assumed as radius, $s\,p$ will be the tangent of the angle mentioned, and $v\,p$ its secant: consequently, all the sides of the triangle $w\,v\,p$ are attainable; and the triangle H X v being similar in species, its sides will also be determinable from the data premised.

Let a represent the line $w\,q$ or $q\,v$

b ———————— $q\,p$

d ———————— $w\,p$

g ———————— $w\,v$, the level line of flotation.

y ———————— q H

u ———————— C q

We then have the following equations and proportions $u\,y = a\,a \therefore u = \frac{a\,a}{y}$

As $a : u :: b : y \therefore a\,y = b\,u = \frac{b\,a\,a}{y}$ and $y\,y = b\,a$ consequently $y = \sqrt{b\,a}$ say $= m$.

Then

Then as $b\text{-}a : g :: m\text{-}a : \frac{mg\text{-}ag}{b\text{-}a}$ = line X v; which will give the position of the interſection of the lines of flotation. The value of q H having been acquired, that of C H the inclined line of flotation follows of courſe. The lines X H and v S will be attainable, by the ſimilar proportions of the two triangles $p\,w\,v$ and H X v as above ſtated; and X H $\times \frac{v\,\mathrm{S}}{2}$ will give the area of the triangle immerſed by heeling *. The mean centres of gravity of the triangles immerſed and raiſed out of the water (viz. *a* and *d*) will, according to well known principles, be at two thirds of the diſtance from X along the lines X r and X t; theſe lines biſecting the oppoſite faces of their reſpective triangles; then C H (the inclined line of flotation) being aſſumed to be horizontal, the horizontal ſpace between r and t will obviouſly be a mean between the lines C S and $w\,n$: and as S H and $s\,n$ are equal, it will therefore be a mean between C H and $w\,s$: conſequently the horizontal removal of the triangle of immerſion will be $\frac{\mathrm{C\,H} + w\,s}{3}$, viz.

$$\frac{\text{the inclined line of flotation} + \overline{\text{the level line of flotation} \times \text{N. S. Ct. of} \angle \text{ of heeling}}}{3}, \text{ (rad. I.)}$$

The level line of flotation of the boat in queſtion being 13.4375 feet, and the angle of heeling 5° 44′ 21″; the area of the triangle in queſtion will be, according to the preceding deductions, 2.26728 ſuperficial feet, and its horizontal removal 107.5398 inches. The conſequent lateral removal of the immerſed centre of gravity will be 6.0915 inches, viz. as 40.027 feet, the ſection of the boat immerſed when laden : 107.54 inches, the horizontal removal of the triangle of immerſion; : : 2.2673 feet, the magnitude of the triangle immerſed by heeling : 6.0915 inches, the lateral removal of the immerſed centre of gravity, which, divided by .1, (the natural ſine of 5° 44′ 21″ when radius is 1.) will raiſe the metacentre 60.915

* The angle of heeling in the diagram (*fig.* III. *plate* III.) is 12°, which is more than double what I have ſuppoſed to take place in Canal boats, and is drawn of that magnitude to make the explanatory lines more ſeparate and diſtinct.

inches

inches above, 20.148, the height of the centre of gravity immerſed, and fix it at 81.063 above the bottom of the boat, viz. 39,513 inches above the centre of gravity of the boat and cargo, which will give a power of reſiſtance equal to 71.15 tons upon an arm of lever of 3.9513 inches, viz. a ratio of 281.13 tons and inches; a reſiſting force far ſuperior to what is needful, and, conſequently, the boat cannot ever heel ſo far.

According to the rules for upright ſided boats, the volume of the triangle immerſed would be $\frac{\text{the line of level flotation} \times \text{N. Tt.} \angle \text{ of heeling, (rad. I.)}}{8}$ $= 2.26835$ feet. The ſpace of removal, at two thirds of the width of level of flotation, would be 107.5 inches; which, multiplied by the ſum preceding, gives a ratio of 243.847 in ſuperficial feet and linear inches. The ratio, according to the method above proceeded on is 243.823 : therefore, under ſmall overhanging of the boats ſide, the operation may be ſhortened for all practical purpoſes, by adopting throughout the ſame rules as for upright ſided boats.

The power that was mentioned as neceſſary to be guarded againſt is that of the wind. To judge of that extent of it, under which the boat may be navigated, with the wind on one ſide, the beſt criterion will be drawn from what falls under univerſal obſervation. I have found from different experiments, that wind mills generally begin to reef their ſails; and ſhips cloſe-hauled to reef their topſails, when the wind blows with an impulſe of two pound on a ſuperficial foot; and under ſuch preſſure it is pretty clear, that a flat boat oppoſing an extended ſurface to a ſide wind, could not be kept off the leeward bank, without greater head-way than is uſually given by track horſes; conſequently, no further reſiſtance of moment has to be guarded againſt.

The height of the waggons when the boat has heeled 5° 44′ 21″, will be leſs than 6 feet above the water's ſurface. The whole range of them will be 60 feet long, and, admitting the projection of the ends of the boat to be equal to the vacancies in the lower part of the waggons, we have $60 \times 6 \times 2$, viz. a force of 720lbs. acting on an average height of 3 feet above the water

waters ſurface. The reſiſting point will be nearly half the draught of water of the boat, which, if it have twelve inches depth of keel, will be a little more than 2 feet below the ſurface: conſequently, the above force would act with an arm of lever of 60 inches, and be equal to a ratio in inches and pounds of 43200. viz. 19.285 tons and inches, which, compared with the reſting power, is upwards of $14\frac{1}{2}$ to 1. therefore, from any other cauſe but that of avoiding the being blown aſhore, there is nothing material to prevent the deck being raiſed nearer the laden water line.

As various caſes will ariſe different from thoſe I have aſſumed, I ſhall conclude with giving a theorem on the equipoiſe of ſtability, coincident with the rules inveſtigated by theoretic authors on Naval Architecture, and ſufficiently ſelf-evident to need no demonſtration.

Let s repreſent the natural ſine of the angle that may be heeled, radius being 1.

d the diſtance between the centre of gravity of the boat and cargo and the metacentre = line $g\ m$, *fig.* V. *plate* I.

w the weight of the boat and cargo.

Theſe combined, viz. $s\ d\ w$ will form the reſiſting power to overturning.

Let p repreſent the quantity or preſſure of the power tending to overturn the boat, or to keep it in equipoiſe in any poſition.

b the arm of lever with which it acts.

Then we have the equation of $s\ d\ w = p\ b$. from which the value of any one of the requiſites to a ſtate of equipoiſe may be found, where the reſt are given.

CHAP. V.

On the Application of Wheel Boats and Inclined Planes to Collieries, and Inſtances in which that Syſtem may be improved.

THE uſual method, in the great coal countries, is to lay waggon or railways from the different pits leading to one general way, which terminates at the river or navigation, where the coals are to be diſcharged: ſome of which railways are in Northumberland and Durham, from 6 to 10 miles in length.

The mode that ſhould be adopted muſt depend on the diſtance the article has to be conveyed to the main river or navigation; and on the form or poſition of the intervening ground, which I ſhall claſs under the three following general heads.

1ſt. Planes nearly horizontal, or with moderate declivity, and without valleys.

2d. Gently declining countries, with deep valleys leading to the river or navigation, taking off the coal.

3d. Mountainous countries.

In the firſt inſtance, if the horizontal line point towards the place of diſcharge, a Canal of ſome ſpecies is clearly eligible, if the length require it: but, if the courſe of diſcharge be in the line of gentle declivity, a railway would generally be the beſt. In the ſecond inſtance, viz. of deep valleys; it is ſufficiently plain, that ſome part of the bottom of the vale would be a proper place for diſcharging the water of the colliery by a drift, which would

would either reduce the lift of the water, or lay the colliery quite dry: In either inftances, particularly the latter *, the drift may, as obferved in a preceding Chapter, be made navigable for boats of about four † feet width, fuitable to the bafkets or boxes, in which the coal may be brought from the face of the works, and be continued as a Canal along the fide of the vale, until it attain the level of the flat country. Then, if the diftance to the river or navigation be fhort, or otherwife unfavourable for the continuance of the fmall boats, they may difcharge their contents to be led away in waggons. But if, by defcending to the bottom of the vale, a confiderable length of level can be obtained in a proper direction, an inclined plane for the boats may then be advifeable.

In the 3d inftance, that of a mountainous country; there, generally, will be fufficient difference of elevation on a regular acclivity, tranfverfe to the line of Canal to obtain long levels: If otherwife, a rail-way will clearly be the beft.

If a Canal be refolved on in any of thefe inftances, it will become a matter of enquiry, what mode of it fhould be adopted: but, previoufly to the difcuffion of this point, I will confider how far wheel-boats may be made ufe of under-ground.

In the great coal mines of Worfeley, there are Canals on three different levels. The firft is on the level leading all the way to Manchefter, which branches to the right and left in every feam of coal that it paffes through: in each of which, by means of drifts at regular diftances, the coals are brought down the declivity of the feam to the boats.

* In this, the navigation would, of courfe, be continued through the level of every feam of coal interfected.

† Boats of this width will frequently be fufficient if the coals be brought out in boxes or bafkets fuited to the land conveyance in the mines. The bafkets, if circular, are in moft places called Corves, and when fquare, or if with fledge bottoms, their name is more local.

It is obvious, that the diſtance which the coals may be brought down, will progreſſively become ſo great as to be attended with material expence: From this cauſe, the Duke of Bridgewater has fouud it convenient to run other levels through his coals at a height conſiderrbly ſuperior to the tunnel from the Mancheſter Canal, which interſects all his ſeams, and from which other Canals branch, as already obſerved.

The higher Canal where it croſſes the main tunnel, has a pit communicating with the ſide of it, down which the coals are ſent from the upper to the lower boats, and by their deſcent raiſe a proportionate quantity of limeſtone up another pit to the ſurface of the ground. The charge of the operation is not great; but the frequent delay attendant upon this method, is ſuch, as may render it eligible in ſome inſtances to convey the boats themſelves from the upper to the lower Canal*; and in all ſituations where the dip or fall of the ſeam is ſufficiently great, for the weight of the laden boats to overcome friction and other impediments to drawing the light ones up, I conceive the ſyſtem of inclined planes and wheels under the boats might be adopted with advantage. It may likewiſe ſometimes be ſo, where the navigation through the coals is below the principal level; but, in both caſes, if the coals have to be drawn up a pit, it will frequently be better to communicate between each Canal and the pit, by a navigable ſtone drift; the propriety of which muſt be determined by the probable coſt of the drift, and the quantity of coals that would have to paſs through it.

Parallel Canals along the ſeam of coals, if eaſily executed, would be eligible every 2 or 300 yards, at leaſt, and would require ſo many drifts or tunnels to the pit. The more diſtant tunnels would become long and expenſive; therefore, if the depth of the pit and the feeders of water be not very conſiderable, it is obvious, that new pits ſhould be ſunk to correſpond with every Canal, or every other one, according to circumſtances. If the inclination of the ſeam be moderate, and it be not eligible to ſink more pits than one, it will be adviſeable to ſink deep enough to correſpond with

* They were laſt year preparing to do this, by cutting an inclined plane through the ſtone and other ſtrata, which I am informed is now completed.

the

the furtheſt propoſed Canal through the coal, and to run a navigable tunnel to interſect it. The intervening Canals through the coal, may communicate with this tunnel, where they croſs it by pits, down which the coals may be lowered to other boats. This may be rapidly done by proper machinery, as the baſkets * or boxes will only have to be lifted above the ſides of the upper boats: but, where the quantity is very great, it may often be adviſeable to form ſteep inclined planes for wheel-boats, taking care, of courſe, that the extremities be ſufficiently horizontal.

I by no means deſign to infer, that ſubterraneous Canals are proper in all collieries. Thoſe, whoſe beds of coal lie nearly horizontal, and are much troubled with dykes or fiſſures, raiſing or depreſſing the ſtrata on each ſide, and have, at the ſame time, but one workable ſeam are under the worſt predicaments; as the re-obtaining of the level of the Canal, in the coal, on croſſing a dyke, would be attended with a comparatively great length of ſtone drift, and no opportunity afforded of ſtriking into any other ſeam, brought nearly to the ſame level, by the riſe or fall of the ſtrata on the other ſide. Alſo, in collieries favourably circumſtanced for the formation of Canals through their ſeams, they can only be eligible where thoſe Canals communicate with ſome other navigation, as at Worſeley; or their depth below the ſurface, or other cauſes, prevent the propriety of having pits near to each other. The ineligibility of many pits in deep collieries, particularly where the water is to be drawn a great heght, is often ſuch, as to render ſubterraneous Canals eligible, under a conſiderable degree of the unfavourable predicaments mentioned.

As the Duke of Bridgewater is the parent of Canals in theſe kingdoms, and the country ſtands highly indebted to him, I ſhall draw another example from his collieries, to explain how the coals are raiſed from the ſeams below the level of his great drift or tunnel, that communicates with the tranſverſe branches.

* Theſe baſkets or boxes being the ſame as the coals are firſt filled into at the face of the workings, unleſs, from local circumſtances they be very ſmall, and then it may be eligible to ſhoot them into larger boxes as at Worſeley.

The

The boats in the lower Canal contain a number of ſquare boxes exactly filling them acroſs, and ſtanding cloſe to each other. The coals being filled into theſe boxes, the boats are then brought under a pit ſunk from the ſide of the main tunnel from the Mancheſter Canal; to which, by means of water tubs deſcending from the ſurface of the ground to that tunnel, the coal boxes are drawn, and are then placed in other boats to convey them away.

In diſtricts where the coals are not conveyed out of the mines by drifts as above-mentioned, but up coal pits to the ſurface, and have to go from thence a conſiderable diſtance; they may either be filled at the mouth of the pits into wheel-boats and ſent forward, as already deſcribed by ſmall Canals to the coal-ſtaith or main navigation: or they may be ſent in waggons to be placed on the decks of boats—Likewiſe, whenever coals in large quantities, lime, lime-ſtone, or other minerals, have to be conveyed along Canals where there is a ſcarcity of water, it will be eligible where it can be done, to overlap the levels in a ſteep place, and communicate them by an inclined * plane for boats, or a double rail-way for waggons, leaving the lock communication to anſwer all the general purpoſes of commerce, and to occupy as ſhort a ſpace as it can. But, where there is no aid of exiſting Canals, and circumſtances are favourable for long levels, I think, that in place of wheel-boats from every pit, which would inevitably, in a ſhort time become leaky, it would be better to make uſe of waggons to go into ſmall boats, in a ſingle range, and for one horſe to draw a couple of them. The points then to be attended to, will be, that the boats occupy as little width of Canal as may be, without being liable to overturn, or to draw too much water for fords.

Conſonant to theſe requiſites, a boat of 6 feet 6 inches width of bottom, and 3 feet 6 inches height, with each ſide overhanging three quarters of its vertical height, to the extent of two feet above the bottom, and then

* This may be eligible where branch Canals on the ſmall ſcale bring in a great quantity of carriage; but if otherwiſe, and there be a general ſcarcity of water not to be remedied by reſervoirs, then the methods of Mr. Weldon or Mr. Rowland, or ſimilar plans, muſt be reſorted to.

curving

curving upwards ſo as to make the full width only 10 feet 6 inches, will be found ſuitable; as at 36 feet length (excluſive of the ends) it will carry 4 chalder waggons, at nearly 2 feet $3\frac{1}{2}$ inches draught of water.

I propoſe two of theſe boats to be drawn by one horſe; and ſteered by a ſhort ſteer-beam, fixed as already deſcribed. If both ends of the boats be ſquare, they muſt be kept ſo far aſunder as to admit of forming a ſufficient angle in ſteering.

The ſole alteration of the waggons from thoſe deſcribed before, is, that I propoſe their wheels to be 18 inches, in place of two feet diameter; and the height of their bodies 3 feet 6 inches, in place of 4 feet: which deficiency of height will be compenſated by making the bottom one foot wider than the former, and nearly of the ſame length as the top, which will only require an additional ſet of falling leaves at the bottom.—Theſe waggons, admitting the raiſed heap of coals to average ſix inches above them, will carry their centre of gravity (with the ſame allowance as to wheels, &c. as in the preceding eſtimate) at two feet one inch above their bottom; which being three inches above the axis of their wheels (of 18 inches diameter and treading 15 inches above the boats bottom) fixes the centre of gravity of the cargo at 4 feet 4, or 52 inches.

The boat may draw leſs, but will be aſſumed to draw 9 inches water: its width of flotation will then be 7 feet $7\frac{1}{2}$ inches, and the weight of one waggon, of 68 Cwt., reſting on 9 feet length, will ſink it; as already obſerved, to nearly 2 feet $3\frac{1}{2}$ inches.

The centre of gravity of the boat will be nearly at 15 inches from its bottom, ſo that the difference between the two centres, will be (52—15) =37 inches. Their proportionate gravities, according to the premiſes, will be 5.28 and 13.6, ſo that the mean centre of gravity will be raiſed 26.65 inches and be at 41.65 inches from the bottom. At 2 feet $3\frac{1}{2}$ inches draught, the laden width of flotation will, in the form deſcribed, (vide *plate* III. *figure* 2) be nearly 9 feet 10, or 118 inches; which, according to the approximate method of proceeding, deſcribed in the preceding chapter,

ter, will, on heeling $5° 44' 21''$ raiſe on one ſide, and immerſe on the other, a triangle of 1.2146 ſuperficial feet, and remove its centre of gravity $78\frac{2}{7}$ inches, which will remove the centre of gravity of the whole maſs, of the ſection 18.88 ſuperficial feet, 5.060 inches laterally, and fix the metacentre at 50.6 inches above the centre of gravity immerſed: which, according to the rules already explained, will be nearly at 14.7 inches; and, conſequently, the metacentre at 65.1 above the bottom, and 23.45 above the centre of gravity of the boat and cargo, which is above all reſiſtance that can be required. However, as, from the narrowneſs of the boat's bottom, it may have the appearance that it will be otherwiſe when it is light; I ſhall alſo inveſtigate the circumſtances of it in that caſe.

The light waggons being aſſumed, as before, at 15 cwt.; and occupying 9 feet length, their ſection of ſupport in the water will be 3* ſuperficial feet, the increaſed depth 4.55 inches; and the boat's line of flotation 98.325 inches (correſponding with 13.55 inches draught.)—Then, admitting the centre of gravity of the light waggons to be 2 feet 4 inches above their tread, or 3 feet 7 inches above the bottom, which is full as high as it ought to be; and taking, as before, the boat's centre of gravity to be 15 inches, there will be a difference of 28 inches, which proportioned according to their maſſes, will fix the mean centre at 25.145 inches above the bottom. The centre of gravity immerſed is according to the premiſes, at 7.035 inches, and the effect of heeling $5° 44' 21''$ well, according to the calculation for boats with overhanging ſides, remove it 6.51472 † inches laterally, ſo as to fix the metacentre at 72.1822 inches above the boat's bottom; and conſequently 47.0372 inches above the centre of gravity of the boat and cargo: therefore, there will be a weight of 8.28 cubic feet of water on an arm of lever of 4.70372 inches = 2434. lbs. and inches ‡, on every foot length, to reſiſt any overturning force; and as the waggons in

* That of the light boat is 5.28, and conſequently the whole is 8.28.

† Triangle immerſed .829098 removed 65.061, as 8.28 : 65.061 : : .829098 : 6.51472.

‡ $4.70372 \times 8.28 \times 62\frac{1}{2}$ (the weight in lbs. of a cube foot of water = 2434 lbs. and inches. N. B. Where the weight has been calculated in tons, 36 cubic feet of water have been aſſumed as a ton in place of 35.84.

the

the light boat will, when heeling, be 5 feet above the water's furface, and the half depth will then be about 10 inches; there will, with a wind of two pounds to the fuperficial foot, (admitting the waggons to occupy the whole length) be an overturning force of 10lbs. × 40 inches, = 40olbs. and inches, which will leave a fpare refifting force of 2034lbs. and inches; equal, as the top width of the boat is 10 feet 6 inches and the line, *m n*, 59.66 inches, to a weight on the gunwale of 34lbs. on every foot in length, which is more than there ever need be, and confequently no impediment can arife, if the boat be kept going with fufficient velocity to prevent it from being driven afhore to leward.

According to the method of calculation purfued for upright-fided-boats of the fame width of flotation line, the triangle immerfed would have been .8434, and the fpace removed 65.55, which would raife the metacentre above the centre of immerfion nearly $\frac{1}{40}$ part more than true calculation, viz. 1.622 inches; which, where there is much room to fpare, as in the prefent and preceding inftance, would be of little moment: but, where the metacentre barely rifes above the conjoint centre of gravity of boat and cargo, the difference, under large angles of overhanging of the boat's fides, will be material.

In *figures* 1 and 2 of *plate* III. M. G and E fhew the pofitions of the metacentre, combined centres of gravity of boat and cargo, and centres of gravity of the part immerfed, when the boats are laden, and under the given inclination: and *m*, *g* and *e*, *fig.* 2, fhew the fame pofitions when the waggons of *fig.* 4 (of which, *fig.* 2, is the profile) are empty. Whence it appears that *o m* is the arm of lever, with which the weight of the boat and waggons refifts any overturning force; and *m n* (which is equal to the fection of the angle of heeling, the half width of the boat being radius,—the fine of the angle of heeling, the vertical * height of the metacentre above the de-

* This vertical height is the fine complement of the angle of heeling, when the radius is the difference (on the bifecting line of the boat) between the metacentre and the height of the boat's gunwales + the fine of the angle of heeling, the half width being radius.

In practical inftances, the admeafurement on the line *m n* on the *figure*, or diagram, may fuperfede the calculation.

preſſed gunwale being radius) is the arm, with which any weight upon the gunwale would act.

As the boats, No. 1 and 2, are propoſed to reſt with their cargoes in docks, they are neceſſarily flat bottomed, and the flat part ſhould at leaſt extend as wide as the railways of the waggons, that they may have a firm ſupport. The form of *fig.* 2 is calculated for a limited depth, in a narrow Canal; and ſo as not to cut its banks, and may be improved by ſwelling out the ſtreight part of the ſide in a gentle curve. *Fig.* 1 admits of being conſiderably ſo by adopting the curved form of the ſides ſhewn by the dotted lines; which, by leſſening the injury to the Canal-banks, would more than compenſate any greater expence there may be in conſtructing the boat, or in obtaining proper knee timbers of that form. The caſual injury to the banks from particular forms of boats, although of no immediate moment to the boat owner, is of material conſequence to the Canal proprietors, and deſerving of attention in their bye-laws.

To enter into a diſcuſſion of the correct methods of obtaining the depths of immerſion, the lines of flotation, and metacentres under thoſe forms, would be unneceſſary; as the reader will clearly ſee, from the preceding examples, approximate methods of obtaining them ſufficiently near for all practical purpoſes.

Theſe boats, as already deſcribed, ſhould be laden and delivered in a dock, nearly of their form: the bottom of the dock, to prevent accidents from ſtones being thrown in, may conſiſt of a number of tranverſe ribs, ſufficient to ſupport the boat; and with cavaties between them. The ſame circumſtance ſhould, of courſe, be attended to in the dock for the large boats.

It has already been ſuggeſted, that the ends of the boats may be of leaves to be let down: which, being ſo narrow as only to admit the wheels to paſs, will be no way unmanageable; and, in boats carrying two ranges of waggons, ſhould conſiſt of two parts, viz. a ſeparate * leaf for each range:

* It is ſcarcely neceſſary to ſay that they muſt ſhut againſt a lining of bend-leather, or of coarſe woollen, or other compreſſible ſubſtance, to keep them water tight.

and,

and, they need only be at one end, unleſs the inconvenience of turning the boat be deemed of moment.

As thoſe ſingle ranged boats are propoſed, principally, for the uſe of collieries, and for the ſaving of railways, which are not only expenſive in the firſt conſtruction, but even in their maintenance; it remains to be conſidered how far the propoſed Navagation will come within proper bounds as to charge.

This muſt depend on the nature of the country, which I have ſufficiently claſſed, and deſcribed. The dimenſions of the Canal need be no deeper than for the wheel-boats, viz. 3 feet 6 inches in clear water, and 2 feet 6 inches over the paved fords: but, it will require to be 5 feet broader in the bottom than eſtimated for thoſe boats, viz. to be 14 feet at the bottom and 24 feet 6 inches on the water's ſurface in place of 9 feet, and 19 feet 6 inches. The difference of expence will be inconſiderable. Each running yard of level cutting will contain 7½ cubic yards of earth, which at 4d. would only be equal to 2s. 6d.; to which is to be added the track-road, highway bridges, tunnels, &c. &c.; all of which will depend on local circumſtances: but, in favorable ſituations, will coſt leſs than a double railway of timber only, and not require nearly the repairs, and be attended with the advantage of a horſe drawing 8 large waggons in place of one.

CHAP. VI.

On the application of Inclined Planes to the Great Rivers of America, or on the Continent of Europe, with Obſervations on the Navigation of Rivers and Lakes.

GREAT rivers, in their natural ſtate, are moſt of them unnavigable in dry ſeaſons for any conſiderable extent, through want of ſufficient depth of water in the rapids; and if navigated from their mouths to their head branches, they frequently uſe different veſſels, as in the Ohio, for the conveyance of the ſame cargo in different diſtricts of the river, according to the depth of water, the gentleneſs or rapidity of the current, and the means of advancing againſt it.

In the higher diſtricts, many of thoſe veſſels would be ſuited for paſſing on carriages, up or down inclined planes; and might, with propriety, be transferred by ſuch conveyance to different levels of canal, ſo as eventually to paſs through any gap of the Allegany Mountains, or of any other ridge, ſeparating rivers of contrary courſes; but, in the rivers themſelves, inclined planes will very ſeldom be adviſeable, particularly in thoſe that riſe 15 or 20 feet or upwards. The banks of ſuch rivers would not often, without great expence, admit of a guard Lock and Canal from the head of a fall, to ſuch diſtance downwards, as to place the head of the inclined plane out of the reach of the floods. The inclined plane navigation in rivers would always be dependent on Locks, to the extent of the riſe of floods; and at thoſe periods the riſe uncovered below the Locks would, in ſmall falls be trivial, if any thing at all, and attendant with all the trouble of paſſing great heights. The expence of their conſtruction would, likewiſe, be nearly the ſame. In rapids, the declivity would, in general, be too gentle to uſe the inclined planes in dry ſeaſons, without the aid of a long

long collateral Canal: and the quantity of defcent would moftly be too inconfiderable to render the ufe of thofe planes eligible. Therefore, they would rarely be fuitable in rapids, and never in fmall falls. In the large falls they can feldom be advifeable, but in the higher parts of the rivers, where only canoes or batteaux are ufed. The Cohoes fall, near the mouth of the Mohawk, may be an exception on account of the general rapidity of the river.

The falls of the Potowmack, above Wafhington, differ from the preceding inftance, in their occupying a confiderable length of the river, in place of being precipitous, like the Cohoes, which is 75 feet perpendicular; and in the Potowmack, being fuited for much larger veffels than the Mohawk.

The great falls of the Potowmack are 14 miles above the City of Wafhington, and defcend 72 feet in one and a half miles length of the river. The little falls defcend nearly 37 feet in about two miles length, and are four miles above the City. In the year 1794, there were fix Locks building to pafs the upper falls, and three to pafs the lower *.

The length occupied by falls, will not, fimply in itfelf, militate againft inclined planes, becaufe there are many inftances where a Canal, on one level, may be continued from the head of a feries of fmall falls, to a fteep declivity at their termination, where the whole fall may be obtained at once; but in general, it will be found lefs expenfive to adopt different levels, fuited to different portions of the fall, to which the Locks may alfo be fuited.

Inclined planes, according to fome of the methods mentioned in the firft Chapter, and explained in the fubfequent one, may be applicable to veffels of 15 or 20 tons, but would not, I think, be eligible where there is plenty of water, and proper fituations for Locks and their intervening ponds: as

* Obfervations on the river Potowmack and City of Wafhington, publifhed at New York, in 1794.

Locks on an economical plan, and complete in their effential parts, might (where materials are at hand, as they generally are in fuch fituations) be built on falls not exceeding 30 or 40 feet, at as little expence as a double inclined plane and its apparatus; and with fuch boats would, in all cafes, be attended with lefs hazard. In lower falls, if even precipitous, Locks and their Canals would be the lefs expenfive of the two methods.— In great falls, as already implied, much will depend on the length of river occupied by the fall, and the circumftances of its adjacent fhore.

In general, in great rivers, where partial contraction will not give depth in the places wanting it, or the current is too rapid to be navigated againft, Locks have decidedly the advantage.

It not being the defign of this effay to difcufs how far Rivers or Canals are preferable to each other, I fhall confine myfelf to a few general obfervations.

Rivers, with fimilar declivities and impediments, and of equal magnitude as to the quantity of water paffed to the fea in the courfe of the year, may be effentially different as to the duration of time they may be navigable. If fupplied from great lakes, their navigation will be more uniform and more fuited for boats afcending, than if more immediately effected by rains. Much alfo depends on the foil, the fuperior ftrata, and the declivity of the adjacent country, as to the abforbtion and flow tranfmiffion of incidental rains.

In fuch great Continental rivers as have not the aid of lakes to equalize the paffing off of the ftreams that fall into them, the winter's fnow in cold climates, anfwer, to a material extent, the fame end; as, in the courfe of their diffolving, they give a confiderable duration to the navigable period, which fo far as it may be fhorter than it would be with the intervention of lakes, is counterbalanced by an increafe of depth; which, in fome inftances, is of more moment than longer duration. In warm climates, the fame end is produced by the length of the periodical rains.

When

When a country is thinly inhabited, and the objects are few, or not valuable, or capable of floating themſelves, any temporary water conveyance is of moment; although only practicable in freſhes or after the melting of the ſnow. As population and commerce increaſe, it becomes adviſeable to remove ſuch impediments, in thoſe rivers, as are eaſily effected, and, then, if the chief part of the conveyance be downwards, and no cataracts in the way; and timber to build temporary veſſels be convenient, and labor not high, the principal objects are attained, as is the caſe on the Duna, and on the Ruſs; where hemp, flax, &c. are brought down on rafts of fir timber, and in temporary veſſels of 2 or 300 tons burthen, all which come down in the flooded ſeaſon.

Theſe veſſels are flat bottomed, and ſlightly conſtructed for the paſſage* down only; being afterwards broken up for fire wood, or any purpoſe. For thoſe objects the Navigation deſcribed is prefereable to any other that is attainable; as the current of the river effects, what would require the aid of many horſes in the Navigation of a Canal, excluſive of the charge requiſite to reimburſe the expence of forming it, which circumſtances more than counterbalance the conveyance againſt the ſtream of a comparatively ſmall quantity. The inconveniences of that conveyance, depend on the duration of the dry ſeaſons; the magnitude of the boat which the river will admit of, and the means of advancing againſt the ſtream. A ſtrong and favorable wind is undoubtedly preferable to all other means; but, in general, is too uncertain. Of the remaining methods, hauling is the beſt, but it requires a ſhore free from trees and buſhes, and ſufficient depth of water at no great diſtance: poling, or ſetting, which cannot be done where there is much depth of water, is the next, and rowing is the worſt † of all: yet, even under the laſt predicament, the Navigation againſt the ſtrong current of the Miſſiſſippi, from New Orleans to the mouth of the Illinois, a diſtance of about 1200 miles by the courſe of the river, and near to 700 in a di-

* Where rivers are of ſufficient depth, as from the lower part of the Illinois down the Miſſiſſippi, ſea veſſels may be built, and diſpoſed of with their cargoes, as has been in contemplation.

† With the ſtream it is clearly the beſt.

rect

rect line, was performed* by the French traders in little more than ten weeks, with twenty oared boats carrying 20 tons, consequently, admitting 30 men to be a proper crew for one of these boats; which would allow the people, during the day, to row two hours and rest one; the expence of conveyance (the boat excluded) would be equal to about 105 days wages of one man, for conveying a ton of goods the distance of 700 miles, or one days wages for nearly 7 miles, in a direct line; which, in the usual circuit of Canals, may be estimated at about 9 miles. This, at the rate of wages in a populous country; and such a country only could afford Canals, would be fully as cheap, even upwards, as boatage and Canal dues. Downwards, the advantage is decidedly great, as the passage would be performed in about a fourth of the time, and with vessels of greater magnitude. Thus, it clearly follows that, in point of political economy, extensive rivers are, generally, far preferable to artificial Navigations; and all that is left for man to do, is to endeavour to remove the obstacles in them, or to pass those impediments by Canals and Locks suited to the species of boats that the river admits of: but, towards the sources of these rivers, where they become small, and have many rapids, the time will probably arrive, when the temporary Navigation they are capable of, will not be equal to the wants of the country; and collateral Canals will be requisite. At this period, the land will have become valuable: it will, therefore, be adviseable, in a rising country, to lay out those lines approximately on its first settlement; reserving a proper width for them, in the original grant of the lands, with power to exchange the land of that line, for any other found more convenient, on a full investigation; and, thus, avoid all the difficulties attendant on those measures in England.

The general preference that I have given to great rivers over artificial Navigations, will by no means universally hold, of which many instances might be adduced.

The river St. Lawrence, from Montreal to Kingston at the entrance of Lake Ontario, is about 160 miles; eight leagues of which is widely ex-

* Vide Captain Harry Gordon's Journal, in Appendix to Governor Pownal's Topographic Description of America.

panded,

panded, and forms Lake St. Francis, where the current of water, if any at all, muſt be trivial. The upper part of the river is gentle; but the remaining diſtance of nearly 100 miles, is a ſeries of rapids *, which makes the Navigation difficult, even with batteaux carrying 35 to 40 cwt. The paſſage depends partly on the wind on Lake Francis, which frequently delays the batteaux for ſeveral days. The whole paſſage, from Montreal to Kingſton, is ſometimes performed in 9 days, or in leſs time, but is, generally, from 2 to 3 weeks, or upwards, ſo that they do not average 10 miles a day, and that with great labour, generally with 8 men poling againſt the ſtream; and occaſionly, as in other ſimilar rivers, getting into the water, and hauling the batteaux over the ſhoals. They often perform the voyage downwards in 3 or 4 days; but, on account of the danger of running againſt rocks or ſtones with the great velocity they deſcend with, they only carry about half the lading which they take upwards.

The freight up, is, as I am informed, generally 16s. per barrel of 280lb., equal to 6l. 8s. per ton for the whole diſtance, or 9½d. per ton per mile: conſequently as dear as land carriage in ſome parts of England. In this inſtance, the utility of a Canal becomes obvious; notwithſtanding the St. Lawrence has the advantage of iſſuing from great lakes.

Upwards, from Port Kingſton, packets, or ſea veſſels, of 2 to 300 tons or more, navigate Lake Ontario: and, obviouſly, can carry articles much cheaper than batteaux, or canoes, which are ill-ſuited to large lakes; unleſs ſheltered from the wind, by the ſhore or by iſlands. There are, however, many inſtances where imperfect Navigations admitting of diſpatch, are preferable to others, much cheaper, that are attendant with delay, which ariſes from the ſame principle, that land carriage, by waggons, is preferable to ſea conveyance; and the more expenſive carriage of articles, by coaches, preferable to either: but this can only take place in articles of high value. On this principle, canoes of birch bark, carrying from 3 to 4 tons in packages of 80 or 100lbs. weight, are navigated, by about 14 men, from Montreal to Machilimakinac, frequently in 15 days, aſcending from Montreal

* Here and throughout this work, I include rifts (or ſmall falls navigable for canoes or batteaux) under the general denomination of rapids.

up the Outawa, carrying the cargo and canoe paſt the ſide of ſeveral ſteep falls on that river, and over the carrying place from it to lake Nipiſſing, through which, and down the French river, they proceed to lake Huron, and along its north ſhore to Machilimakinac. The whole of this diſtance is nearly 600 Engliſh miles, and clearly proves that falls and portages are impediments far inferior to long continued rapids. The ridges of rocks, which form the falls, penn up the water above them, and anſwer, naturally, the ſame purpoſe as Locks and Weirs, in ſtilling the current, and giving depth of water, which Governor Pownal has juſtly obſerved in his Topographic account of America.

With articles of ſuch high value as furs, that have alſo to be collected in different rivers, and conſequently, with the goods ſent to purchaſe them, the line of navigation deſcribed would probably be eligible, if even a ſhip communication were open between lakes Ontario and Erie.

In mixed navigations, where Lakes, Rivers, or Canals alternate with each other, and where the lakes are ſo ſmall as not to admit of the expence and delay of tranſhipping the cargoes at each end, the commerce will be beſt carried on in boats that are not too large for rowing, particularly where there are any narrow paſſes among ſhoals, through which ſuch veſſels as the river would otherwiſe admit of, could not turn to windward, and where towing paths could not be conſtructed. In theſe caſes, boats incapable of rowing, would often be ſo long delayed by contrary winds, as to add more charge on the tonnage conveyed, than would take place in boats of 10 to 20 tons, capable of both rowing and ſailing; excluſive of the decided advantage ariſing from ſuperior expedition, and from the leſs delay in lading and delivering, particularly if the cargo have to be collected in different packages. But, where the quantity of commerce is great, and the articles bulky, then, wherever practicable, it will be adviſeable to paſs ſuch lakes by a collateral Canal.

The

The Czar, Peter the Great, ſet a praiſe worthy example in the Canal of Ladoga, through which there paſſed in the year 1778 *, four thouſand nine hundred and twenty-ſeven veſſels, which, through the large lake of Lagoda would have been attended with great danger and delay, particularly as the veſſels are, from the nature of the upper Navigation of the rivers, and other cauſes, ill ſuited for the paſſage through ſuch a lake.

Having given my ſentiments againſt inclined planes, on the great falls in the lower parts of rivers, on the foundation, principally, of changing the article of conveyance, we may now examine their eligibility where a neceſſity of that change takes place.

A communication between the lakes Ontario and Erie, for the ſhipping that navigate thoſe lakes would be highly deſireable; as then, the ſame veſſels might navigate the lakes Michigan, Huron, Erie, and Ontario :— but the height ot the cataract of Niagara †, and the fall and continued extent of the rapids are ſuch, as to preclude at this period, the idea of ſuch a navigation : therefore, as tranſhipping is requiſite, and great falls are ſuited to inclined planes, that ſyſtem, as being attended with diſpatch and ſmall expence, appears ſo far to be favourable.

Deficiency of local knowledge muſt prevent a deciſive opinion on what meaſures ought to be adopted; but I can ſcarcely heſitate to ſay, that wheel-boats would be ineligible even there, becauſe of their incapability of carrying many of the articles wanted to be transferred, and their being totally unſuitable to enter the Streights of Niagara: conſequently, if inclined planes be there preferable to other methods, it muſt be on the plan of con-

* Travels through Sweden, Ruſſia, Denmark, &c. by W. Coxe, F.R.S. Since that period, I ſuppoſe, the number has conſiderably increaſed.

† The fall of Niagara is about 240 feet, and, incluſive of the rapids immediately above, and for about three leagues below, is ſuppoſed to be more than 400 feet. Were it ſimply like the falls of St. Mary, ſeparating lake Superior from lake Huron, the magnitude of the object in the preſent ſtate of population, would probably warrant ſuch an undertaking as a navigation for ſhips.

veying upon carriages, boats of 8 or 10 tons, more or lefs *; wher upper termination be at the end of the prefent portage above th rapids, or extended fo far collateral to the fwift running ftrea make the fubfequent navigation perfectly eafy to fhips. In the dicament, it is clear, that after the goods have once been plac to go upwards, and brought to the end of the Canal and rapids, it muft be more eligible to take the boats forward by t ftream where it is weak, than to permit the fhips to come d they could not depart without a ftrong and favourable gale ; cipal trade, as to bulk being downward, it is clearly the b articles down ftream without the fhips.

In the remaining predicament of continuing the Canal entrance of lake Erie, to fome port or place where fhips mi to wharfs, dividing them from a bafon at the head of the Cana boats in queftion would, as already faid, not be eligible, throu capacity of taking in feveral of the articles, and their being ill conveyance of many of the others.

* Probably lefs in the firft inftance ftated, and more in the latter.

CHAP. VII.

Description of the Internal Navigation of China, with Remarks on its Principles, and further Observations on Rivers and Inclined Planes.

SIR George Staunton's acconnt of the travels of the late Britiſh Embaſſy in China, affording an ample deſcription of the artificial navigations of that Empire, which lays claim to a longer and more uninterrupted period of civilization, than any other nation of the globe: I preſume a few comments on the ſkill they have attained in overcoming aſcent and deſcent, the great difficulties in that art, will not be unacceptable even if attended with no inſtruction. I ſhall, therefore, avail myſelf of the information given in the account of the Embaſſy, and draw from thence ſuch concluſions as it may warrant.

The Chineſe, in their interior navigations, appear to have exerciſed leſs of the inventive than the imitative powers; as all their attempts in that uſeful ſcience, amount to nothing more than a ſervile imitation of Nature, in the navigation ſhe affords upon thoſe rivers, where the quantity of water is ſuch as to give depth, notwithſtanding the inclined poſition of their ſurface. Where that inclination is ſmall, they have obſerved that both depth and width of ſurface may be combined, but that where it is great, the one of theſe muſt ceaſe to be extenſive; and where from natural cauſes, the width has done ſo, a navigable depth has ſtill been retained, notwithſtanding the rapidity with which the water runs off: they have alſo obſerved, that thoſe rapids, even when contracted, are not navigable in dry ſeaſons in the ſmaller rivers, which naturally ſuggeſted the idea of preventing the waſte of water when not immediately wanted for the paſſage of boats; from whence aroſe the plan mentioned in 4th article of the 1ſt Chapter of this work,

work, which the Chinese have pursued as well as the Europeans, probably without either copying from the other.

On these principles, they have invented their justly famous Canal, which, running through an extent of upwards of 500 miles, conjoined with the aid of natural rivers, gives, with the exception of one carrying place, an interior navigation nearly from the North to the South of the Empire, through an extent of upwards of 16° of Latitude, viz. from Tong-schoo-foo within 12 miles of Pekin, to Canton, the great mart for their foreign commerce.

To effect this purpose, it was only requisite to unite the Yun-leang-ho, or Eu-ho, with the river Yangtse-Kiang, a distance of about 350 geographic miles in a direct line, which the comparatively flat state of the intervening country easily admitted of; as the fall from the summit, either way, did not exceed that of many navigable rivers. On this principle, they contrived to separate the river Luen-ho, which running from the Eastward from a higher level than the summit of the Pass, they divided into two distinct channels, the one running North to the Eu-ho, and the other South to such part of the Yellow River as had sufficient elevation to admit an artificial branch from it, to discharge part of its waters into the river Kiang; from whence, as already mentioned, they had a natural navigation to Canton, with the exception of one carrying place. Here the artificial navigation for the great purpose of traversing the Empire ended; but, as the river Kiang had sufficient elevation at this place to admit of a new channel to the head of the arm of the sea West of Tchuzen, at Hang-tchoo-foo, on the river Chen-tang-chiang *, within the flow of the tide; which,

* The termination of the Canal is in the Pe-hoo, a small lake adjoining the town and river, which forms a bason for the vessels, which are exceedingly numerous here and throughout, and exceed all ideas that could have been reasonably formed: They are, indeed, confined to the navigation of the Canal and Rivers it communicates with to the North, there being no navigable connection between the bason and the adjoining river, (probably from the fall being too great to be conquered by their flood-gates) and consequently, Hang-choo-foo has become a great Emporium.

In

which, from this place for 60 miles downwards to where it joins the sea is of such expanded width beyond its natural channel, as rather to deserve the name of an arm of the sea, as I have already termed it. This great width, combined with its extensive shoals, has apparently induced the patient and industrious Chinese, to construct a Canal nearly collateral to it, to a smaller river, so as to give them a more certain and safe communication with Tchusan, which lies in an island forming with others a safe harbour, a little without the entrance of this inlet of the sea.

The extension of the Canal to Hang-tchoo-foo, has also afforded them an opportunity of avoiding the great lake Poyang, about sixty miles in length, through which the usual route to Canton lies, which, so far as boats are used as a mode of travelling, and probably for other purposes they found eligible to do: although, at the expence of a Portage between the heads of the Chen-tang-chiang and Quang-sin-ho, which latter discharges into the lake Poyang, but communicates by artificial channels with the Kan-kiang-ho, near its discharge into that lake, which disembogues itself into the river Kiang, and adds considerably to its magnitude, although its course is upwards of 2000 miles.

The Kan-kiang-ho is then to be navigated for 300 miles, mostly against a strong current, to the foot of a ridge of mountains, separating it about 30 geographic miles, in a direct line from the navigable part of the river Pe-kiang, which runs through 260 miles to Canton.

These rivers were navigated in their higher or shallower parts by the Embassy, in lightly-constructed covered barges, described in one place to be sharp built at the ends, flat-bottomed, about 12 feet broad, and 70 feet in length; they sailed well, used cotton sails, and drew very little water, and, with a brisk and favourable breeze, made no inconsiderable progress

In the carriage of grain from the Yun-leang-ho, or grain-bearing-river to Tong-schoo-foo near Pekin, there is supposed to be at least 1000 Junks employed; each containing fifty inhabitants, the boatmen living in them with their families. Besides which, an immense number of other vessels, equal at least in population, are employed in other commerce.

againſt the ſtream without the aid of trackers. The trackers to each barge, it appears, were generally about 15 men relieved alternately. In ſome parts of the river Chen-tang-chiang, the peaſants were employed to deepen a channel through the ſhoals, although the barges drew leſs than a foot water, which is not unuſual in European rivers in dry ſeaſons.

In almoſt all the rivers as they deſcended to deeper water, they changed from theſe light barges to junks, which alſo navigated the Grand Canal; and when they aſcended the rivers to where they became ſhallow, they again quitted the junks for light barges, which latter they uſed throughout their navigation of the Chen-tang-chiang, the whole courſe of which above Han-choo-foo, where they embarked upon it, does not exceed 200 miles.—Theſe junks contained two tier or ranges of apartments, were conſequently heavier and drew more water, but it does not appear that they uſed more trackers to them than 18 or 20: whence it follows, that theſe rivers have, fortunately for the Chineſe, but moderate falls. It has, indeed, appeared to the Embaſſy, that the river Kan-kiang * has an average fall of 20 feet per mile, which is very far beyond what it can poſſibly have, according to the circumſtances of its navigation. With thoſe not actually experienced in improving the navigation of rivers, ſuch an opinion was not unlikely to take place, and no way leſſons the general merit of the information on this ſubject, which appears to be collected with attention, and is diffuſely ſcattered through various parts of the work, to which the reader muſt be referred, as I ſhall only extract ſuch parts as are immediately neceſſary for my purpoſe. I ſhall, however, previouſly make ſome further obſervations on the fall of navigable rivers, as it involves the circumſtances aſcent and deſcent, and is therefore perfectly conſonant with the purpoſe of this Treatiſe.

* The Yang-tſe-kiang (called by abbreviation the Kiang) below the lake Poyang to the ſea, a diſtance of 300 miles, is ſuppoſed by Sir George Staunton to have 1000 feet fall. This river, where entered, and left by the Canal, was about two miles wide, with a current not exceeding two miles an hour in the ſtrongeſt part; and much deeper than (the Yellow River, which was not more than) 9 or 10 feet deep in the middle of its ſtream.

In Major Rennell's interesting account of the river Ganges and Barrompooter, he informs us, that " a section of the ground, in length 60 miles " parallel to one of the branches of the Ganges, was taken by order of " Mr. Hastings, and found to have about 9 inches descent per mile in a " straight line; but, the windings of the rivers were so great, as to reduce " it to less than 4 inches per mile." This appears to have been in the dry months, and where the mean width of the Ganges was ¾ of a mile, its mean depth between 15 and 20 feet, and its velocity somewhat less than 3 miles an hour. This noble river is navigable for an extent of 1350 miles, with vessels from the size of a wherry up to 180 tons; but those of 30 to 50 tons are accounted the most eligible, and are tracked against the stream so as to advance along the shore about a mile and an half per hour.

The river Amazon, which, with its branches, affords by far the most extensive interior navigation in the world, has, according to the barometric observations of Monf. de la Condamine, still less descent below where its current is undisturbed by rapids; and runs with as great, if not a greater velocity than the Ganges, the velocity in many places being upwards of 5 miles an hour.

Although these velocities are beyond the medium of what the yatches and barges of the Embassy could be tracked * with their number of men; and they also must, from their being in shallow rivers, have kept generally in the full stream, which is not the case in large rivers; yet, I do not mean to infer, that the Kan-kiang-ho had no more fall than the Ganges or Amazon.

* The author has observed a boat of light construction with only 14 tons lading, of 8 feet width of floor, about 10 feet width of water line, and 50 feet extreme length, drawing 2 feet 3 inches water, and sharp at the ends, dragged against a stream whose velocity was 5 ½ English miles an hour; and, although there were 28 trackers, besides three men in the boat poling it on, it only advanced at the rate of ¼ of a mile an hour. The channel was not materially contracted in either width or depth of water way, in proportion to the section of the boat, which would of course have added to the resistance.

The fall of rivers upon the same length of channel, and under similar velocity of current, will, I conceive, depend on the sinuosity of their course, the uniformity of their sections, the want of depth, and the retardation or friction the water meets with from the nature of the channel. The number of bends in similar instances in any given distance, Major Rennell very justly observes, "depends on the magnitude or width of the "stream." One of half the width is capable of taking twice the number of meanders: These, by the perpetual reflection of the course of the river, destroy much of its original impetus; and, consequently, through an equal length of channel it requires a greater declivity than a straight river to continue the same velocity. Diversity of section also operates the same way; as wherever it increases, the water necessarily diminishes its velocity nearly in a similar ratio, and has to re-acquire it where again contracted; which, consequently, requires a further fall sufficient to regenerate the difference of velocity.

The third and last causes I have mentioned, are the want of depth and nature of the bottom. Want of depth, with even a smooth bottom, occasions considerable friction to the sheet of water immediately superinducing it, which communicates a portion of it to the next, and so forward, as to retard the whole sensibly to a considerable extent *; as may be seen in the borders of all rivers, which consequently proves, that want of width likewise retards the current. That want of depth does so, is clearly shown by the water of the inundations over the Delta of the Ganges (over which the boats navigate against the stream) scarcely exceeding half a mile an hour, whilst the mean motion of the Ganges at that period, notwithstanding its meandring, is from 5 to 6 miles an hour.

The circumstance of progressive retardation of the mass of water by shallowness of channel, is further proved by the different strata of the

* This extent will be greater in shallow rivers, than in deep ones; as the mass of water above is equally operative in preventing that retardation by its friction, and were it not so, a larger portion of the light matters would be found in the substrata of islands or bordering grounds, formed by the deposit of rivers.

islands

iflands of the Ganges (and in all other rivers where iflands are formed by depofits) being progreffively of particles lefs denfe as they approach the fummit. Although lighter and heavier matters are afloat or commixed in the water on the firft commencement of its depofites, yet only the moft denfe can fubfide, the force of the ftream being fuperior to the refiftance of the others; but, as that force declines, lighter and lighter matters are capable of refting until it finifhes with vegetable foil or the lighteft particles, which, as obferved by Major Rennell, will hold their place neareft the furface of the water.

In fhallow water, the nature of the bottom operates very importantly: For inftance, where rocks are ftanding in the ftream, but fufficiently wide afunder to leave a navigable paffage, they fo far return back the current of the water, that I have known, in depths of 4 or 5 feet, a velocity of not more than 5½ miles an hour, with a fall exceeding the rate of 20 feet per mile; but this was only in falls of about 2 feet to 2 feet 6 in one continued extent, and with deep and wide pools between, under which predicament boats may, with great force of trackers, (far beyond what the Embaffy had) navigate againft an average fall of 10 feet per mile.

Another caufe of retardation of current is weeds, which in the latter part of the fummer, when the water would otherwife be low, give in many rivers with a fall of 2 to 3 feet in a mile, a depth of about 2 feet 6 with a general velocity of lefs than a mile an hour. From what has been faid, it appears that, in rivers of long courfe, the original impetus is of inferior moment; and that it is of little confequence at a diftance from the point of outlet, whether the navigable part of a river commences from a lake, or immediately below a rapid torrent, as its effect would be nearly loft in the firft expanded fection of the river, and, admitting a uniformity of channel, it would progreffively be reduced in fome ratio, inverfely, to what a head of water fufficient to generate a velocity equal to the firft impetus, would bear to any fubfequent defcent of the river combined with that head, which would foon render the effect of that impetus infignificant.

I ſhall now reſume the information to be derived from the travels of the Embaſſador and his retinue, in their route from Pekin.

The Embaſſy embarked on the river Pei-ho, at Tong-ſchoo-ſoo, about 12 miles from Pekin, in covered barges of about 70 feet length, and 15 feet width, and only about 10 inches draught of water, with their paſſengers, and ſuch portion of their baggage as they took on board. The river was then become ſo low as to cauſe the boat to be dragged with difficulty over ſeveral of the ſhoals. After 60 miles of navigation, they arrived at the tide-way, and in 30 miles further, arrived at Tien-ſing (about 60 miles from the ſea, or gulf of Pe-chee-lee) at the confluence of 3 rivers, up one of which, the Yun-leang-ho, or Eu-ho, running from the ſouth, they proceeded in the beginning at the rate of about a mile an hour, againſt a ſtrong current by the force of 18 or 20 trackers: as the river was confined within narrow bounds between two artificial banks, for the apparent purpoſe of given depth. Above it was wider, deeper, and more gentle. Up this river they proceeded nearly 2½ degrees of latitude to the city of Lin-ſin-choo, where they entered the Imperial Canal which is carried in a line almoſt directly South, and nearly parallel to the general line of the ſea-coaſt. "This enterprize, the greateſt and moſt ancient of its kind, which "was found to extend from Lin-ſin-choo to Han-choo-foo, in an irre-"gular line of about 500 miles, not only through heights and other val-"leys, but acroſs rivers and lakes." It is ſaid by Sir George Staunton, to be "often winding in its courſe, of unequal and ſometimes conſiderable "width, and its waters ſeldom ſtagnant." On its junction with the Eu-ho, the Canal was cut through ground of the height of 30 feet, to permit its water to flow with a gentle current into the Eu-ho. The current of the water was moſtly ſlow; and to prevent its running off too rapidly, its deſcent is occaſionally checked by flood-gates, which were ſeldom ſo near as within a mile of each other. Theſe flood-gates conſiſt of two abutments of ſtone, one projecting "from each bank, leaving a ſpace in the middle "juſt wide * enough to admit a paſſage for the largeſt veſſels employed

* The width, according to the Plate, appears to be a little more than 21 feet. According to De la Land, leſs than 30 feet.]

"upon

" upon the Canal." Few parts of the Canal are entirely level; and they have overflows or paſſages through the banks to prevent the water riſing beyond a given extent; and alſo to prevent unneceſſary waſte of it through the flood-gates, the paſſages are occaſionally cloſed by planks let down tranſverſly and ſeparately one above another, their ends reſting in a vertical groove in each abutment. " Some ſkill is requiſite to be exerted, in order " to direct the barges through them without accident. For this purpoſe, " an immenſe oar projects from the bow of the veſſel, by which one of the " crew conducts her with the greateſt nicety. Men are alſo ſtationed on " each pier with fenders made of ſkins ſtuffed with hair, to prevent the " effect of the veſſels ſtriking immediately againſt the ſtone, in their quick " paſſage through the gates, which are only open at certain ſtated hours, " when all the veſſels collected near them in the interval paſs through on " paying a ſmall toll. The loſs of water occaſioned by the opening of " the flood-gates is not very conſiderable, the fall at each ſeldom being " many inches, which is ſoon ſupplied by ſtreams conducted into the " Canal from the adjacent country on both ſides. The fall is, however, " ſometimes above a foot or two, when the diſtance between the flood-" gates is conſiderable, or the current rapid. The Canal was traced often " in the beds of ancient rivers, which it reſembled in the irregularity of " its depth, the ſinuoſity of its courſe, and the breadth of its ſurface, when " not narrowed by a flood-gate. Wherever the circumſtances of the ad-" jacent country admitted the water in the Canal to be maintained in a " proper quantity, without any material deficiency or exceſs, by means of " ſluices managed in its ſides, for the purpoſe of influx or diſcharge, as " was the caſe farther to the Southward, few flood-gates were neceſſary " to be conſtructed, nor were there any where met with more than half a " dozen in a day."

On the higheſt part of the Canal, which by the map is about one-fifth of its entire length in proceeding from the North, " the river Luen, the " largeſt by which the Canal is fed, falls into it with a rapid ſtream, in a " line which is perpendicular to the courſe of the Canal. A ſtrong bul-" wark of ſtone ſupports the oppoſite weſtern bank; and the waters of the

" Luen

" Luen ſtriking with force againſt it, part of them follow the northern, and " part the ſouthern courſe of the Canal."

In proceeding from the ſummit to the South, the Canal, or artificial river, paſſed by the verge of the Lake, and was there ſupported on high embankments, to enable it to paſs over ſome riſing land farther South, through which it runs at leaſt 20 feet below the ſurface of the adjacent ground. The Canal afterwards paſſed collateral to the Lake of Wee-chaung-hoo, which " reminded the Embaſſador of the great Canal of " Ruſſia, with which he was well acquainted. This ran in like manner, " at certain diſtances parallel to the Lake Ladoga, from which it was ſe-" parated by vaſt earthen embankments." From this circumſtance, it is poſſible, that Peter the Great (although his genius was equal to the ſuggeſtion of any thing uſeful to his country), may have borrowed the idea from China, as previous to the formation of the Canal of Ladoga, he had a direct acquaintance with the Chineſe Empire, by an Embaſſy * in the commencement of his reign, in the year 1693, whilſt his brother John ſhared the throne conjointly with him.

At a further diſtance, " the Canal widened, flowing to the ſouthward in " a current of upwads of 2 miles an hour. Several branches went off " from the main trunk of the Canal, on which, as well as on the diſtant " Lakes ſeveral barges were ſeen ſailing. During the next ſtage, the " Canal was conducted again through low grounds ſubject to inundation, " with Lakes and Moraſſes intervening."

* The Embaſſador, Everard Iſbrand, was neceſſitated to go through the ceremonious proſtrations of the Chineſe, which the prudence and firmneſs of the Britiſh Embaſſador, aided by the good ſenſe of the Chineſe Emperor enabled him to avoid. In another Embaſſy from the Czar Peter to the Court of Pekin, in the year 1719, his Embaſſador Leoff Vaſſilovich Iſmayloff, was under the ſame diſagreeable conſtraint as his predeceſſor. According to Father Du-Halde, a former Embaſſy from Moſcovy in the year 1631, was not favourably received, becauſe the Embaſſador would not ſubmit to the Chineſe ceremonies. Theſe obſervations are quite irrelevant to the ſubject of this Treatiſe, and are only inſerted on the preſumption that, to many readers they may be acceptable at this time, when the circumſtances of the Britiſh Embaſſy have attracted the public attention.

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It then approached the Yellow River into which it falls by a gentle current. The Canal is here about three quarters of a mile in width, and forms an excellent harbour for the veſſels navigating it. The Yellow River has here run through a courſe of 2200 miles, and is not more than 70 miles from the ſea: " Its width little exceeds a mile, and its depth in the middle " of the ſtream is not more than 9 or 10 feet, and its velocity is about 7 " or 8 miles an hour," which it appears to continue downwards, conſequently, there is a conſiderable fall to the ſea, which enabled a deſcending branch to ſtrike off ſouthwards to the river Kiang. " On the ſouthern " ſide of the Yellow River, the yatches began to proceed more quickly; " the current of the Canal as it quitted that river being more rapid, in " conſequence of which, the number of flood-gates were increaſed upon " this part of it; farther on, it was carried by the margin of the Lake " Payo-yng, whoſe ſurface was much lower than that of the Canal, which " was ſeparated from the Lake by a ſtrong embankment. Beyond the Lake " there was again ſwamps and moraſſes."

" In the midſt of the low grounds of this part of the route, a town of " the third order * was ſituated; the tops of its walls being little more " than level with the ſurface of the Canal, which formed an aqueduct raiſed " 20 feet, was 200 feet in width, and ran at the rate of three miles an " hour. This Canal, on proceeding ſomewhat further, ceaſed to have a " current; and the ground riſing to the ſouthward, it was found neceſ- " ſary, in order to give level, to cut down about 20 feet deep for a track " of 7 or 8 miles, to a large city where not leſs than a thouſand veſſels of " different ſizes were lying at anchor."

" In three days after the yatches had croſſed the Yellow River, they came " to that of Yang-tſe-kiang, which is conſidered to equal, if not exceed

* The cities of the third order terminate their names with *ſhien*; the ſecond order with *tchoo*; and the firſt with *foo*, which three deſcriptions are ſurrounded with walls. Many of the cities appear to have increaſed within this century, as ſeveral of them which Du-Halde has terminated with *tchoo*, have now the additional termination of *foo*.

" the

" the ſize of the former. It was at this place about two miles wide. The
" current where the yatches of the Embaſſy paſſed, did not exceed in the
" ſtrongeſt part of it two miles an hour; but it was much deeper than the
" Yellow River.

" The ground to the ſouthward of the Yang-tſe-kiang gradually roſe to
" ſuch a height, that it was found neceſſary to cut down the earth in ſome
" parts to the depth of near 80 feet, in order to find a level for the paſſage
" of the Canal."

High ſtone arches, ſome of them elliptic, the longer axis vertical, and high enough to take junks under ſail, are erected over the Canal, and are aſcended and deſcended by ſteps. They have alſo bridges over the piers of their flood-gates, which, to prevent interruption to the maſts of veſſels, are conſtructed ſo as to be eaſily withdrawn when veſſels are about to paſs. They are flat wooden bridges, narrow and light, each reſting on rollers fixed in its frame, and running on a couple of looſe ſpars that are withdrawn after the bridge.

The Canal, in its courſe through the city of Sou-choo-foo, divided into various branches through the ſtreets as in Venice. Some idea of the importance of the commerce of this city may be entertained, from the circumſtance of 16 veſſels of 200 tons each, being on the ſtocks in one ſhip-builder's yard.

Near this city, " the great Canal was without a current, and ſo wide,
" that a ſtone bridge of no leſs than 90 arches was in one place thrown
" over it: the Canal continued to be of a width between 60 and 100 yards,
" and its banks generally faced with ſtone for about 90 miles in length,
" between Sou-choo-foo and Han-choo-foo.

" A large irregular baſon at Han-choo-foo terminates the Imperial
" Canal. It is increaſed by waters from a lake lying to the weſtward of
" the city; the latter furniſhes alſo a copious ſtream running in a channel

" round

" round the city walls, and ſmall Canals paſs through its principal ſtreets.
" This baſon diſcharges into the river Chen-tang-chiang, which falls into
" the ſea at little more than 60 miles to the eaſtward: the tide when full
" increaſes the width of the river to about 4 miles oppoſite the city, but
" at low water, leaves on that ſide a level ſtrand of nearly 2 miles width."

From the preceding extracts, an idea may be formed of the magnitude and diverſity of this great Canal, as to width and velocity of current, which being variable, frequently in counteracting degrees, viz. often narrow in deep ſinking, where the water is nearly ſtagnant, and wide where the ſtream runs with conſiderable velocity; it follows, that to give depth in the rapid ſtreams, additional rivulets muſt be taken in, and diſcharged again in the commencement of the ſtagnant parts; which it appears is their mode of proceeding, as they have overflows to diſcharge their ſuperfluous water, which is frequently applied to irrigation; and they repeatedly receive additional influx where it is neceſſary.

There now only remains to be noticed their Inclined Planes, which are particularly deſcribed in the route from Hang-choo-foo to Tchuſan, which was purſued by Colonel Benſon and Captain Mackintoſh, of the Hindoſtan, after they had parted with Lord Macartney, and the remaining attendants of the Embaſſy, who followed the route already deſcribed to Canton.

The Tchuſan party croſſed the river and entered a ſmall Canal. After they proceeded about three days, they arrived at the city of Loo-chung, where they changed their inland barges for junks of about 60 tons burthen each, neatly fitted up for paſſengers, but conſtructed for ſalt-water navigation, and lying on a river into which the tide flowed beyond Loo-chung. They ſailed from thence to Nimpo near Tchuſan; the river was of the breadth of the Thames between London and Woolwich.

Before their arrival at Loo-chung, " it ſometimes happened in the
" route to Tchuſan, that the water of a higher Canal paſſed immediately

" into another of a lower level; and in two inftances the travellers were " launched in their barges with prodigious velocity down the ftream *. " The upper Canal is bounded by a ftrong and well-compacted wall, the " top of which is level with the furface of the upper water. A beam of " wood is laid on the upper edge of the wall, which is rounded off towards " the water. Beyond (or below) the wall, a floping plane of ftone work " extends to the lower Canal in the form of a glacis, with an inclination " of about 45°, and defcending near 10 feet in perpendicular depth; at the " bottom of which, the Canal is carried along as the level of the country " will allow, when another wall and glacis for another Canal ftill lower, are " conftructed as before.

" In paffing from an upper to a lower Canal, the veffel lifted over the " crofs-beam flides down by its own gravity, and to prevent the water " from flufhing over the decks, or her plunging into the Canal below, a " railing is fixed at the head of the veffel about to be launched, before " which is placed a ftrong matting at the time of its defcent. To draw " up a large veffel from the lower Canal along the glacis into the upper " Canal, requires fometimes the affiftance of near a hundred men; whofe " ftrength is applied by means of bars fixed in one or more capftans, " placed on the abutments on each fide of the glacis. Round the capftans " is a rope, of which the oppofite extremity is paffed round the veffel's " ftern, which is thus conveyed into the upper Canal, with lefs delay than " can be done by locks, but by the exertion of much more human force; " a force, indeed, which in China is always ready, of little coft, and con" ftantly preferred there to any other."

* It appears, from this defcription, that water was running down the Inclined Planes; and if fo, it is accordant with fome of the defcriptions of the Jefuit miffionaries. This, however, is probably only occafional; and caufed by the fluctuation of the furface of the Canal.

The

This defcription of the Chinefe inclined planes, appears to be correct in the outline, but cannot be taken literally, as 45° declivity is far too fteep, unlefs the fall be fo little as to bear a fmall proportion to the length of the boat; and then the fteep inclination of the plane would be of little moment, as the boat need never touch it but on fliding off with its heel.

In the plate, the defcription is partly corrected, as the inclination is but 14° from the horizon, viz. one foot fall for every four feet bafe, which is alfo too fteep, unlefs the boats that pafs thofe planes be much fhorter than the general run of their boats; which is the more probable, as otherwife, they would ftrain and break in two with any lading, on turning over the crofs-timber at the head of the plane. Thefe boats, according to the plate of the inclined plane are of about 3 feet height, and 56 feet tread on the ground, with fharp overhanging ends, projecting 9 or 10 feet, and rifing with a bend equal to the defcent of the plane, therefore tending at one end to raife the veffel in its defcent, and at the other to produce the fame effect, in a fmall degree, by the weight of the boat's end behind the tread of her heel. I fhall affume the boat to be fo far laden as to have as much buoyancy above as below water, and the effect of the projecting ends to be under that predicament, equivalent to a fhortening of it to 8 feet lefs than its tread on the ground, viz. to make it equal to a boat of fimilar fection from end to end of only 48 feet, in place of 75 feet extreme length. From thefe premifes, and admitting the tranfverfe fection to be fquare, which will not materially alter the cafe, (as their fection, exclufive of the ends, is uniform), we may deduce what the floating power of fuch a boat would be.

Under this predicament, it is obvious, that a diagonal line from the fummit of one end of the boat to the lower extremity of the other end, would divide its bulk into equal parts, one of which immerfed in water, would be juft equal to its whole weight; therefore, as under the given angle of inclination and weight of boat, the water would only flow 12 feet

 along

along the boat's bottom, or $\frac{1}{4}$ of its length; it follows, that at the instant of immersing one end under water, it would only have $\frac{1}{4}$ of its weight water-borne. The centre of gravity of this tendency to lift the boat would be at 4 feet inwards from its lower extremity, viz. at $\frac{11}{12}$ of the distance from the boat's heel, which latter would be its turning point. It is evident, that a power equal to half the weight of the boat and cargo, applied at its lower extremity, would enable the boat to rise, as the other extremity would bear half the weight *; but, in the present instance, there is only half the necessary power acting at $\frac{11}{12}$ of the requisite arm of lever, consequently, only equal to $\frac{11}{24}$ of the requisite force; therefore, with the aid of matts towards the head of the boat still unequal to the end †. If, however, we combine the description of the fall, viz. "near 10 feet in "perpendicular depth" with the length of plane, in the plans accompanying the work (which the eye might judge of, comparatively with the length of boat) we shall have a declivity of about $\frac{1}{6}$ or nearly $9^{\circ} \frac{1}{2}$ from the horizontal line, which will pretty well accord with the circumstances.

I have entered into this discussion principally to shew the points to be attended to, in the facility of boats floating from off inclined planes, and the necessity either of their being of a gentle declivity on their junction with the water, or that the axis of the hinder wheels be placed not far behind the centre of gravity of the boat.

I can easily conceive, that the travellers might be mistaken in the declivity of the plane, if they judged by the eye, as angles of ascent and descent are

* Nearly so, the turning point being only thrown backward the tangent of the ∠ of inclination upon 1-third of the boat's height. To make the other deductions perfectly true, the centre of gravity of the boat and cargo must lie at 1-third of its height; and if higher, as it generally must be, it will operate more against the power of the boats' rising.

† Unless there were at the bottom of the glacis an apron or smooth platform at such a depth as not to admit the boats to sink, which does not appear to be the case, nor could well be so under such fluctuation of surface as the Canals are liable to.

very

very deceitful in their appearance. That the boats are longer than on reflection we should conceive them to be, appears corroborated by a traveller of the last century, Father le Comte *, who observes, that " in " some places where the disposition of the ground does not permit the " forming of a communication between two Canals, they still contrive to " pass vessels from one to the other, notwithstanding they may have more " than 15 feet height to surmount. At the extremity of the upper Canal, " they construct a double glacis, or inclined plane, of hewn stone. When " a vessel arrives at the extremity of the lower Canal, it is raised by the " help of capstans to the summit of the first glacis, from whence its own " weight makes its slide on the second into the upper Canal, and they de- " scend to the lower by reversing the operations."

This author could scarcely comprehend how the Chinese barges, which are commonly very long and very heavy laden, did not break in the middle when suspended in the air on the angle between the double glacis; nevertheless, he did not learn, that the least accident ever happened.— " These inclined planes (he says), are not to be found in the grand Canal, " because the Imperial barks could neither be raised by manual force, nor " secured from the misfortune to which the others have the appearance of " being liable."

In inclined planes of small fall, such as are used in China, and for boats of considerable length and magnitude, the side-way motion † might be made to answer. It would also do for longer inclined planes (particularly if very steep) by the aid of counterbalancing weights down several pits, and a caisson for the boat and its surrounding water to descend on many wheels, or rollers, into a dock such as described in several instances in the first Chapter. The counterbalancing weights may be cylindric tubs, fitting the pits and laden with water; the two end ones so regulated, as to move

* Vide Belidor's Architecture Hydraulique, Tom. IV. P. 355.

† Ships are sometimes launched this way, where there is want of room to go end foremost.

perfectly

perfectly equal to each other, and keep the caiſſon during its progreſs in the ſame parallel poſition *. The pits ſhould at leaſt be down to the level of the drift, from the dock or lower receptacle of the caiſſon.

The weight of water and of the veſſels in the pits, under ſimilar vertical deſcent with the inclined plane, will theoretically be no more than that of the caiſſon and its contents, be the angle of declivity what it may; and their different ſpaces paſſed through would be eaſily provided for, by the difference of diameters of the wheels, on the axis communicating the counterpoiſing powers; but in gentle declivities particularly, friction and reſiſtance from irregularities of the ſurface acting on the wheels or rollers ſuſtaining the caiſſon, will be very conſiderable, and occaſion a loſs of water far beyond that of the plans of Mr. Weldon or Mr. Rowland; but of little conſequence compared to Locks. Another circumſtance alſo militates againſt this plan in moderate declivities, which is, the difficulty of keeping a large caiſſon water-tight, becauſe of the greater effect from caſual checks under the neceſſarily increaſed velocity. From both the above cauſes, I conceive the plan ſuggeſted, will ſeldom be eligible but in ſteep declivities of 30° and upwards.

It is an argument againſt the inventive powers of the Chineſe, that they have not hitherto conſtructed Locks, as a great part of invention lies in the conception of the poſſibility of the event; and the Chineſe have been informed, for upwards of a century, of its abſolute poſſibility; as the Jeſuit Miſſionaries ſent to China by Lewis the XIVth, in 1685, acquainted them with the principles of a Lock, with which they appeared aſtoniſhed. The Fathers alſo thought that any one who would carry to China the model of a Lock would be well received; and cauſe as much admiration as the firſt watches that the Miſſionariers preſented to the Emperor.

* Chains muſt of courſe be made uſe of in the machine both to ſuſpend the water veſſels and retain the caiſſon. A prejudice, no doubt, exiſts againſt chains, on account of the uncertainty of their ſtrength; but this may eaſily be remedied, by ſubmitting every link to a ſtreſs far ſuperior to what they are propoſed to bear, which may be done before the chain is put together, as for this purpoſe, it ſhould conſiſt of links connected by bolts.

The

The Chinese method of overcoming ascents appears to be long subsequent to the attempts of the Egyptians, under the successors of Alexander; who, according to Monf. Huit, Bishop of Avranches, had the art of constructing sluices, or Locks of one set of gates, so as to stop the impetuosity of the current, and be occasionally opened. Though termed gates, the openings were most probably closed with beams of timber, let down in grooves; as gates of large width and depth could not be opened without difficulty, even against a small difference of level. There are, however, such sluices with gates upon several of the running Canals on the verge of the Shannon. They were erected about the middle of this century, and are of difficult use, because of the force requisite to open them.

These running Canals are on the Chinese principle, and nothing more than new Channels for a portion of the river; which, when it is low, are stopped as in China, to retain a head of water sufficient to pass the boat.

During the flooded state of rivers, all small falls are equalized, as they necessarily rise higher below than above a rapid; therefore, I am far from saying, that running Canals with a small fall are not, in many instances, eligible on the shores of great rivers; and that well-devised stops easily opened and closed, (not such as lift up like those described in China, nor open against the stream as gates) are not sometimes preferable to incurring the charge of Locks.

In other nearly similar instances, where Locks are eligible, their piers and gates alone will be sufficient without any other floor or side walls, than a concave and battered pavement, continued through the bottom and up the sides of the space between the piers.

The eligibility and the particular construction of these works, will much depend on the nature and extent of the beds of the rivers, the difference between their low and flooded states, the height and also the permanency of their shores, and the quantity of floating ice.

These

These single pairs of piers of the Chinese, are properly called by De la Lande, half Locks. The casual position of two pair of piers near to each other, has, no doubt, occasioned the invention of Locks; as it would soon be seen, that when the gates or stop beams of the lower piers were closed, and of sufficient height that the water would be nearly still between the upper pair of piers, and afford an easy passage. On this principle, in place of single pairs of piers, two pair would be erected, sufficiently near to each other for the purpose, and capacious enough to hold a fleet of boats. It would soon afterwards be found, that in dry seasons the waste of water was greater than could be conveniently afforded, and the operation tedious for single boats: thus would progressively arise the invention of Locks with walled chambers, and sluices through their gates or walls.

There are at this day existing on rivers, Locks of the first construction; composed simply of two pair of piers, without any connection of walls or pavement between them.

The following account of the antiquities and description of the Chinese Canals, is principally extracted from Monf. De la Lande's Treatise, " Des Canaux de Navigation;" and from Du Halde's History of China, in which authors will be found a more full and particular account than the design of this essay requires me to give.

The commencement of the Chinese Canals was somewhat less than two centuries before the Christian æra, viz. soon after the coming in of the dynasty of Han, which took place 202 years before Christ. Previous to this, grain and other necessaries were carried on men's shoulders, where they had not the convenience of Rivers or Lakes. The Emperor being shocked at this slavish occupation of his subjects, employed many *ouans* of men (each *ouan* being 10,000), to dig Canals for the conveyance of rice and grain from the provinces to the capital, which was then in the province of Chen-si: and, before the middle of the second century preceding the Christian æra, all the great rivers communicated with each other by Canals, and were navigable almost every where.

Between

Between that period, and the commencement of the dynaſty of Yuen, or the Monguls, which began in 1260, the capital of the empire was ſucceſſively changed into different provinces, which occaſioned new combinations of Canals, for conducting to each new capital the immenſe number of veſſels laden with grain that it required.

Yangti, of the dynaſty of Tſin, who mounted the throne in the year 605, and reigned 13 years, commenced the firſt year of his reign with making new Canals, and enlarging the old ones, that veſſels might paſs from the Yellow River to the Kiang river, and into the river Ouei (Eu-ho of Sir George Staunton) and various other rivers. A plan was given to him for making all the rivers navigable throughout their extent, and to make them communicate one with another by Canals of a new invention. This project was executed, and according to it, 1600 leagues of Canals were made or repaired.

At this period, moſt probably, their plan of flood-gates was adopted; as the new invention could only be in this, or in regulating the water by influx of new ſtreams and diſcharge of ſuperfluous quantities, or in lining the banks with ſtone where the ſtreams were rapid, the remainder being ſimply excavation or embankment.

About the year 1289, the Emperor Chi-t-ſou, the firſt of the dynaſty of Yuen, or according to others, the fifth ſucceſſor of Ghengis-kan, having conquered all China, and being already maſter of Weſtern Tartary, removed the ſeat of empire to Pekin, to be more central to his vaſt dominions. But the neighbouring provinces not being able to furniſh ſubſiſtance to his court and his numerous army, he cauſed to be made, or rather to be perfected and altered, the famous Canal of Yu-ho * or Yun-lyang-ho, (implying the river for conveyance of proviſions), which runs through the empire from North to South.

* From Sir G. Staunton giving theſe names to the river Ouei, between Lin-tſin-choo and Tien-ſing, it appears, that the improvement in the channel of the Ouei, between Tienſing and Lin-tſin-choo, have cauſed it to be deemed part of the Yu-leang-ho.

They had, at firſt, no well-connected plan, but made ſeveral uſeleſs attempts full of faults. They went upon improper lines, and had not ſufficiently attended to the effects of dry ſeaſons and inundations, which were, however, progreſſively corrected.

The general depth of water was deſigned in the great Canal to be 9 feet; and its frequent turns are many of them intended to prevent (in aid of the flood-gates) the too rapid running off of the water. They have frequently a difficulty in keeping up 5 or 6 feet water; and in ſome dry years, the Canal is reduced to 2 or 3 feet, which is not ſufficient for the Imperial barges.

The portage from Nan-gan-foo, over the Mountain Meilin to Canton river, is ſo conſiderable, that the road is, at all times, thronged almoſt as much as the ſtreets of a great town. They are, however, enabled to avoid this portage when the rivers are high; as they have, for that purpoſe, joined a Weſtern branch of the Pe-kiang, (probably that ſtriking off from Tchao-choo-foo) with a river running through the province of Hou-quang into the Yang-tſe-kiang. This appears to be a different river from the Kan-kiang-ho, and to lie to the Weſtward of it. The navigation by this route, is ſaid to be much more circuitous than the other.

The waters which collect from the mountains in the North of the province of Quang-ſi, form near the city of Hin-ngan-hien a ſmall river, whoſe courſe is ſtopped by a dam, ſo as to ſend the water to the ſummit of the paſs by a channel for that purpoſe; from whence, by a ſhort Canal, it joins the two rivers. It is neither ſo convenient nor ſo well kept up as the grand Canal; and the water is often low, ſo that the veſſels are rather drawn on the gravel than on the water. The ſluices or contracted paſſages on this Canal for the purpoſe of ſtopping the water, are, for the moſt part, made of earth ſupported by ſtakes, the paſſage through which is cloſed with mats or other ſimilar things.

The

The induſtry of the boatmen and inhabitants of the country ſupplies all defects, and gives this rout ſufficient advantages to cauſe it to be frequented by many merchants; as in the other rout, a paſſage by land is indiſpenſable, and cauſes much expence and trouble in tranſporting merchandize; however, there is no particular impediment in the circuitous route during the time of high water in the rivers. This circumſtance clears up the difficulty of accounting for the paſſage of the immenſe rafts of timber proceeding for the middle and Eaſtern provinces, which the Britiſh Embaſſy met below Tchao-tchoo-foo; as, by this channel, there is an interior water-communication all the way from Canton, even to the Northern provinces.

In the journey of the Fathers Boures, Fontenay, Le Comte, &c. from the port of Ningpo (the Nim-po * lately mentioned), they relate, that they ſoon "came to a place where they hoiſt up the barks, in order to "convey them to a Canal which is 9 or 10 feet higher than the level of "the river. They hoiſt up the bark by means of a ſlope or declivity, "paved with large ſtones, and when they have got it to the top, they let "it ſlide down another into the Canal." "There are people who wait to "be hired for this purpoſe; they are not above a quarter of an hour about "it, having the help of two capſtans."

This inclined plane is in the ſame diſtrict deſcribed by the Tchu-ſan travellers (probably one of thoſe they deſcended), and differs in nothing but the time of paſſage, which will depend much on the force employed.— If the aid of capſtans be uſed, in which both narrators agree, the paſſage cannot be ſo quick as by a well-regulated Lock. Their account of the Kiang and Yellow Rivers, and of the Canal in their route to Pekin, conſiderably reſembles Sir G. Staunton's. Some of the ſluices or flood-gates upon the great Canals, are deſcribed as retaining the water in confined channels of maſonry (apparently of ſome extent), through which it ruſhes with

* The different names given to the ſame places by different travellers, is eaſily accounted for, when it is conſidered, that their orthography muſt be totally auricular, from the Chineſe not uſing the alphabet.

vaſt impetuoſity, ſo as to require great power of capſtans and of men, to get the veſſels up; and that, in place of letting them run down at will, they are carefully let through by ropes that are ſlacked away, until they are below the ſtrength of the ſtream.

In the Chapter on Lakes, Canals, and Rivers, P. Du Halde obſerves, that "if China happily enjoys ſo great a plenty of every thing, it is in-" debted for it, not only to the goodneſs and depth of its ſoil, but to the " great number of Rivers, Lakes, and Canals, with which it is watered. " There is not a city, nor even a large town, eſpecially in the Southern " provinces, which is not ſituated upon the banks of a River, Lake, or ſome " Canal; and there are few provinces where there is not a large Canal of " fine, clear, and deep water." The principal Canals, L'Abbé Prevot informs us, " diſcharge themſelves on both ſides into a great number of " others, which communicate with moſt of the cities and towns; for the " convenience of travellers, and the tranſport of the products of the coun-" try, which are reciprocally communicated. Theſe little Canals are, " in the end, ſubdivided into a number of brooks to fertilize the adjacent " plains."

As much oppoſition often ariſes in this country to the execution of the moſt uſeful Canals, it may not be improper to repeat the well-known fact, that " Canals in China are cut through any kind of private pro-" perty, gardens, plantations, or pleaſure-grounds; not even thoſe of the " Emperor, or any of his Governors excepted; but when the work ar-" rives at their gardens or pleaſure-grounds, the Governor, or even the " Emperor himſelf, digs the firſt ſpade of earth, and pronounces with an " audible voice, *This is to let thoſe of inferior ſituations know, that no private " pleaſure ſhall obſtruct the public good.*"

It appears, that the river Kiang affords an extenſive navigation, and is, in many places of immenſe depth, and in others has rocky rapids of conſiderable extent, which they find dangerous and difficult. The ſame cir-

cumſtance

cumſtance likewiſe takes place in ſome other of their rivers, which, were they acquainted with Locks, they might remedy. The Yellow River gives alſo an extenſive navigation, but it is difficult to ſtem its current. The Poyang Lake is ſaid to be a dangerous navigation, from ſudden high winds, and that many veſſels are loſt in it; which accounts for the Britiſh Embaſſy being ſent to Canton by a different route.

The Chineſe were much influenced to the conſtruction of that part of their navigation, which is parallel * to the coaſt, by not being expert ſeamen, and their fear of ſhip-wreck and pirates. Cauſes totally different muſt, at ſome period, produce a ſimilar effect in the Ruſſian Aſiatic dominions. The great rivers Oby, Jeniſea, and Lena, which rank among the greateſt in the world, all diſcharge into the Frozen Ocean, ſo that a ſea navigation is totally precluded. Theſe rivers, however, ſo interlock their great navigable branches, in a plain country, as to admit of being eaſily united; and by the two former alone being done ſo, a water conveyance from the Eaſt ſide of the ridge of mountains dividing the provinces of Caſan and Tobolſkoi, would be had to Strealka, near the Chineſe frontier, from which a conſiderable trade is carried on by caravans to Pekin, a diſtance of about 1000 geographic miles, an extent of land-carriage apparently immenſe in this country where every thing is very dear; but there of comparatively ſmall moment. Nothing then would remain to be done, to afford water conveyance from the frontier of China, and from the immenſe provinces of Jeniſeiſkoi and Tobolſkoi to Peterſburg, but to effect ſome of the ſpecies of navigations which I have deſcribed, through the vales of the narrow ridge of mountains between the river Tura, a Weſtern branch of the Oby; and the oppoſite Eaſtern branch of the Kama, from which river there is an extenſive commerce by water to Peterſburg, in the conveyance of ſalt, iron, &c.

* In a populous country, like China, that navigation is ſufficiently diſtant from the ſea, to authorize its conſtruction without thoſe motives, which, however, were a leading inducement.

In

In the travels of Mr. John Bell, from Petersburg through various parts of Asia, he informs us, that the river Ket, a navigable branch of the Oby, above its junction with the Irtish, "takes its rise in a Lake at a small "distance from the Jenisea," (nearly opposite to Yeniseik the capital of the province), "and were a Canal cut between them, which might "easily be done, there would be a passage by water to the frontiers of "China from Verchaturia," a town on the East side of the ridge of mountains West of the Kama, and situated on the Tura, which falls into the Irtish.

I have only stated a navigable communication to Strealka; but from circumstances, it appears probable, that the navigation might extend from two to three hundred miles further, through Chinese Tartary towards Pekin, by pursuing the Selinga, Orchon, and Tola. The latter is a branch of the Orchon, which, as well as the Strealka, falls into the Selinga, which disembogues into the Lake Baykal.—This Lake discharges its waters by the Angara, a branch of the Tongusta falling into the Jenisea above Yeniseik.

Mr. Bell also observes, that from Elimski, a town on the Elimm, a navigable branch of the Tongusta, it is about two days journey to the Lena, from whence it is navigable both downwards and upwards for vessels of considerable burthen. The country between these places is, however, though not mountainous, rather hilly.

The full effect of that communication between the Eastern and Western provinces, those who are acquainted with the country, only can judge. Siberia is, itself, sufficiently fertile to receive vast advantages from a communication between its rivers; and no articles but those of value, would ever traverse the immense distance from one extreme to the other, particularly as, from the shortness of the summers, the passage would rarely or ever be performed in one season. It would extend through above 75 degrees of longitude, or considerably more than one fifth of the circuit of the globe in that parallel.

CHAP.

CHAP. VIII.

General Obſervations and Concluſion.

WHERE the propoſed length of Navigation is very conſiderable, it becomes a great object that the cargoes ſhould be larger than the ſmall ſyſtem admits of, becauſe, many of thoſe cargoes concentered in one, will require leſs aid of men and horſes, conſequently be conveyed cheaper *, and in general ſafer; alſo, the greater detention from lading and delivering, larger veſſels diminiſhes as to its effect proportionately with increaſe of diſtance.

The Lock Navigations admit of the largeſt veſſels, and next to them, the plans of Mr. Weldon and Mr. Rowland, and that ſuggeſted in a preceding Chapter: which latter being leſs limited by phyſical cauſes, is applicable to greater heights with leſs proportionate increaſe of expence: and to a greater extent of fall than either of the others can be eligible: after theſe, follows Mr. Reynold's invention of Locks at the head of Inclined Planes, which, combined with the eight-wheeled † carriages deſcribed, or with the frame and rollers paſſing under, and connected with it, as ſuggeſted by Mr. Fulton, will be applicable to decked

* Wherever the difference of expence of the two Canals enables a reduction of toll, equivalent to the increaſed charge of conveyance, that advantage ceaſes, except as to light or valuable articles, which never can be ſo perfectly ſecured, as under a deck and hatches.

† Theſe carriages are adapted to an Inclined Plane of greater declivity than at its head or foot; but if the declivity be uniform, ſo as to ſuit a carriage with rollers, it will alſo be ſuitable to a carriage with any number of wheels on each ſide; taking care only, that the tread of the wheels form a right line, and that there be means of adjuſting them.

boats

boats of 15 or 20 tons, or perhaps more. The next in rotation *, as to magnitude of cargo, is the inclined plane and carriage ſyſtem for ſmaller or ſhorter boats paſſing over the ridge at the end of the upper Canal, which is chiefly calculated for coals and minerals, and will, probably, admit of improvement, by making the deſcending and aſcending way continuous, like Mr. Fulton's; and having a Lock at the head of the deſcending way, long enough to contain a ſeparate carriage for 3 or 4 boats, (or ſo many as form what has been called a conjoined boat). Thoſe boats on deſcending, would draw another gang light, or half load upwards, over the top of the ridge, no Lock being requiſite on that ſide. The chief objections to this, lie in the vaſt weight of a gang of boats, which, in a ſteep angle of deſcent, would require a very heavy rope, and in the difficulty of returning the carriages to their proper place. The latter may be got over by keeping the two ways at a little diſtance, and joining them above and below by a ſimicircular railway for the carriages (coupled † to each other) to run along under-water, after they have parted with their veſſels.

Both in this, and the method laſt deſcribed, the water contained in the Lock may be drawn off into a reſervoir, at the head of the inclined plane: in this reſervoir, or a pond communicating with it, may be fixed a broad under-ſhot water-wheel between the two railways, to retard the motion of the deſcending boats, and to throw back the water.

This wheel may run in a cloſe caſe, and be divided round its periphery by different ſhroud boards, forming ſo many wheels, ſo that one or more portions of its width may be employed at the ſame time, in throwing up water according to the neceſſity of the caſe, to be determined by the velo-

* In this, I alſo include the methods of boats alternately lowering and hoiſting each other up and down pits.

† In ſuch a way as to ſuit the different boats that are to reſt upon them; and yet admit of the neceſſary extenſion when the boats came over the concave part of the Inclined Plane, which may be effected by a worm-ſpring.

city

city of the descending boats, which, by means of a centrifugal regulator *, will open one or more of the penstocks to let the water below the wheel, or shut them all, as occasion may require. The reservoir under the wheel should, of course, never be exhausted; but when drawn down to a certain extent, should, by a floating weight, or any other method, let in water from the head Canal. These means will answer for a descending trade, and, if the ascending trade be more than the other can draw up, and water be deficient, recourse may be had to a steam engine.

As boats on the aggregated plan may be 7 or 8 feet wide, they will answer tolerably well for light goods, and, as one gang, or combination † of conjoined boats, may be constantly under the same charge, no objection can arise from change of responsibility, particularly, as these boats are not so small but they may safely navigate larger Canals, and without inconvenience, when the conjoined or separate boats are proportioned in length and width to suit the Locks.

Wheel-boats of 4 feet width, may answer well in proper countries for lead, iron-ore, slates, limestone, &c.; and if found to strain at 16 feet length, three of which I have proposed to form one conjoined boat, carrying 9 tons; they may be reduced so, as to carry the same quantity in four, and be connected as one boat: they will also, in certain instances, answer in collieries.

* A contrivance sufficiently known, consisting of a vertical axis (having near the head of it a collar connected with a lever) crossed diagonally with two bars of iron, moving on a pin, which passes at right angles through the vertical axis; on the lower end of each of these diagonal bars is an iron ball. These balls flying off on their receiving sufficient centrifugal tendency to overcome their gravitating force, produce the designed operation, by drawing down the lever; which is done by joints of the same length of the parts of the diagonal bars above their intersection, and joined both to the head of them and to the collar. These joints, and the upper part of the diagonal bars form the appearance of a lozenge. This apparatus is frequently used to regulate the motion of Boulton and Watt's steam-engine, and is called a governor.

† Viz. two or four conjoined boats, according to circumstances.

In addition to the methods mentioned, there is another which belongs more to great diverſity of magnitude of Canal, than to overcoming aſcent and deſcent. This is the quick tranſition of articles from one boat to another, by means of having the cargo in the greater boats, either put originally, or diſcharged into caſes ſuited to the form of the ſmaller ones: conſequently, eaſily transferred to the latter, and as eaſily taken out from them. This has been elucidated in the fifth Chapter, ſo far as it is applicable to aſcent and deſcent.

In the diſcuſſion of every ſubject where a diverſity of opinion prevails, it is requiſite that the writer ſhould be free from prejudice: Engineers have in general been charged with being inimical to the introduction of the ſyſtem of navigation ſo warmly recommended by Mr. Leach, Dr. Anderſon, and Mr. Fulton; which, if eligible to the extent aſſerted by thoſe Gentlemen, would have thrown deſerved cenſure on all who have been concerned in the chief direction of public works: I ſhall, therefore, in an Appendix, ſhew by Extracts from ſome of ſuch of my Reports on projected Navigations as have been printed, that I have been no way hoſtile to the leading principles of their plans, and conſequently, poſſeſs ſufficient impartiality to be guided by no other object than the inveſtigation of truth.

The general concluſion from the whole that I have ſaid, is, that the ſyſtem of narrow Canals is uſeful in various inſtances, particularly for minerals and all heavy articles not liable to damage from water, and much cheaper in particular ſituations, where the declivity of the country runs regularly tranſverſe to the general line of the navigation, and the falls are great; but, that for general purpoſes, and with the uſual circumſtances through which lines of Navigation run, the difference of expence between the two ſyſtems is leſs than might be imagined, and frequently more than counterbalanced by the difference of conveniences: alſo, that Mr. Fulton's boats are too narrow, even for the carriage of coals in bulk, to the quantity they ought to carry, and draw too much water to produce the ſaving of occupation bridges: and that with the increaſe of width and other alterations recommended to ſave occupation bridges, and to prevent the boats from overturning, they would ſtill require, compared with other boats, a greater

greater power of horſes to move any given tonnage with ſpeed, ſufficient to keep them from driving aſhore with a ſide wind:—that they would not carry any due proportion of light or bulky articles:—and that any thing liable to be pilfered or damaged by water, would not be conveyed with equal ſafety: that the boats when travelling far upon land, as ſometimes would be requiſite with coals, lime, &c. would be liable to become very leaky: and that, in theſe inſtances, it would be better to convey thoſe articles in waggons to be carried in boats for the purpoſe; and to ſubſtitute, in place of the narrow Canal, a ſhallow one a little broader:—that Mr. Fulton's boats of 20 feet length, reſting only on two tranſverſe axes, would be liable to ſtrain and become leaky, in the paſſage up and down the inclined planes:—that this circumſtance only admits of remedy from another inconvenience; that of being much ſhorter, and the more of them requiſite to be coupled together to carry any given tonnage:—that, therefore, it will frequently be better to lay aſide the advantage of wheels affixed to the boats, and to follow the Dungannon and Coalbrook Dale ſyſtem of floating the veſſels over ſtrongly framed carriages, on which they will reſt even and free from ſtrains, and may, by the means deſcribed, be of much greater dimenſions than any that are now uſed on inclined planes:—that great Canals with Locks, and ſmall Canals with inclined planes may be made, wherever requiſite from ſcarcity of water or other cauſes, to coincide with each other, provided the great Canals be laid out in as long levels, and as great intermediate deſcents as conveniently practicable, occupying as ſhort a ſpace as may be by the Locks; and overlapping the levels, ſo as to join each other in ſteep places by inclined planes.

In fine, Canals have been, and muſt ſtill continue to be, of dimenſions varied according to the form and ſpecies of the boats deſigned to navigate them: which ſhould differ, ſo as to coincide with the circumſtances of the country paſſed through; the nature of its commerce and products; and the Canals, and Rivers, or Lakes, that muſt eventually be navigated by the ſame veſſels. Thus no general ſyſtem can be adopted, and nothing extenſive can be determined on with propriety, without the aid of great experience and abilities.

N 2 APPEN-

APPENDIX.

*Extracts from "A Report on the Improvement of the Harbour of Ark-
"low, and the Practicability of a Navigation from thence, by the
"Vales of the various Branches of the Ovoca."*

Dublin, 1792.

I SHALL now proceed to the Interior Navigation, which, on account of the declivity of the ground through which the Canal muſt paſs, and alſo the rapid aſcent which has to be ſurmounted to go even a moderate diſtance into the country, does not favourably admit of being entirely carried on by the uſual means.

The ſteep face of the hills the Canal has to run along, will, neceſſarily, confine its width, and produce a ſimilar effect on the width and depth of the boats; which will, likewiſe, in a certain degree, be limited in length by the neceſſity of quick curves round the points of the hills.

Their dimenſions I recommend to be 7 feet width on the gunwale, 5 feet at the bottom, 3 feet 6 depth, and 40 feet extreme length: if properly built, they will carry upwards of 8 tons each, at 2 feet draught of water, and about 11 tons at 2 feet 6.

The

The ſize of Canal ſuitable to them, ſhould be 18 feet on the water line where the banks are ſteep, and in favourable ground 21 feet, to admit two laden boats to paſs; wherever not ſo, for any conſiderable extent, it muſt, at convenient diſtances, be made that width for the length of a couple of boats. Where 21 feet wide, 3 feet 6 inches depth of water will be ſufficient; and where narrower it ſhould be deeper; for, wherever the ſection of the Canal approaches nearly ſo low as only 3 to 1 of that of the boat, conſiderable inconveniencies ariſe both from the increaſed reſiſtance of the boat, and the damage to the banks from the counter current to fill up the ſpace the boat leaves in her rear.

In the proportion mentioned of 3 to 1, the increaſed reſiſtance to any uſual rate of going, will be nearly $2\frac{1}{4}$ * times what it would be in open water, as the boat muſt move 3 feet through the water for every 2 along the Canal bank, and the counter current along the banks will run with half the rapidity the boat goes along the land; from which may be conceived the tendency of narrow Canals to fill up by the waſhing in of their banks, and that the tracking againſt a moderate current in an open river, requires leſs force than the moving in ſuch a Canal, beſides poſſeſſing the advantage of favouring the boats in going downward. Theſe circumſtances I chiefly mention, becauſe the Navigation I ſhall recommend, will be a conſiderable diſtance in the river.

Thoſe acquainted with the County of Wicklow, may reaſonably object to the practicability of extending the Navigation far into the country, on account of the vaſt aſcent, which would be too expenſive to be overcome totally by Locks; but on reflecting that the ſteep and winding face of the hills neceſſarily confine to the uſe of ſmall boats, and that there are ſituations for aſcending at once 70 or 80 feet, or whatever heights may be neceſſary to penetrate into the country, the difficulty will vaniſh; and it will be found, that the means of effecting this work will be ſcarcely half as ex-

* Not uniformly ſo, becauſe at a diſtance from the extremities of any level, the water in front will partly recede without riſing to its full oppoſition; and that in the rear, partly come in to fill up the vacuity left by the boat.

penſive

penſive as the uſual methods of penetrating ſo far, and aſcending ſuch heights in countries favourable for the common ſtyle of Navigation.

Part of the plan propoſed is only applicable to mountainous countries, which enjoy this peculiar advantage, that if the riſe of level be made on a point dividing two rivers, the aſcent enables both valleys to be navigated. This mode of Navigation has its limits in point of eligibility; and, in general, where extenſive, muſt be a mixed one.

Extracts from a Report on the Meaſures to be attended to, in the Survey of a Line of Navigation, from Newcaſtle-upon-Tyne to the Iriſh Channel.

Newcaſtle, 1795.

TO make a Branch Canal, to and through the mining country, of ſimilar magnitude with that propoſed from ſea to ſea, would be extremely expenſive as well as unneceſſary.

On the face of a mountainous country, where there are ſudden bends and little ſoil, boats, from the firſt cauſe, ought not to be long; and, from the thinneſs of ſoil and declivity of the ground, the Canal would be expenſive to be either wide or deep. Bridges would alſo be coſtly, not only from the expence of their erection, but the difficulty of filling their approaches on the downward ſide. I therefore recommend a Canal of only 3 feet 6 inches depth, and at every high and bye road, that there be a paved ford of 2 feet 9 inches depth, the downward ſide of the ford to be an overflow, ſo that the water can never riſe materially higher, and horſes and carriages may at all times ſafely paſs. The width and length of boats on this Navigation, I would adviſe to be half of what they will be on the main Canal; ſo that, if found more eligible than re-ſhipping their cargoes into the large boats, four of the ſmall ones may proceed together, and paſs through the Locks with the leaſt waſte of water that the ſeparate plans will admit of. Theſe boats ſhould be of the conſtruction of the Birmingham

trows

trows (upright fided and flat-bottomed), and when light, fhould only draw 6 inches water;—they will then, at 32 feet length and 6 feet width *, carry, according to the form of their ends, from 8 to 10 tons each, when laden to 2 feet 6 inches:—four of them, which may be navigated with one horfe and four boys †, will, at the leffer quantity, carry 32 tons. Thefe boats fhould be connected together in pairs, each hind one, as in the Lincolnfhire Navigation, acting as a rudder to the fore one, in each of which, from a fmall maft a light track-line may go to the fwingle-tree of the horfe.

In defcending from the line running through the lead country, which probably may be confiderably higher than the branch from the fummit of the main Canal, various meafures may be adopted, either paffing the boats down inclined planes, as at Coalbrook Dale, or perpendicularly ‡, if the advantage of a precipice can be obtained, in each cafe a defcending boat drawing up an afcending one, or by fimple means of difcharging the cargoes of the boats of one level into thofe of another.

But if water be to be had, Locks of a rude and eafy conftruction may, in that country, be executed at nearly as little expence as the inclined planes and requifite machinery, and not fo liable to accidents and mifmanagement from unfkilful men.

So far as relates to the fmall boats propofed to go in fleets of four together, they will jointly confume the fame quantity of water in paffing feparately through one of their own fingle Locks, as they will by paffing collected through one of the large ones on the main trunk.

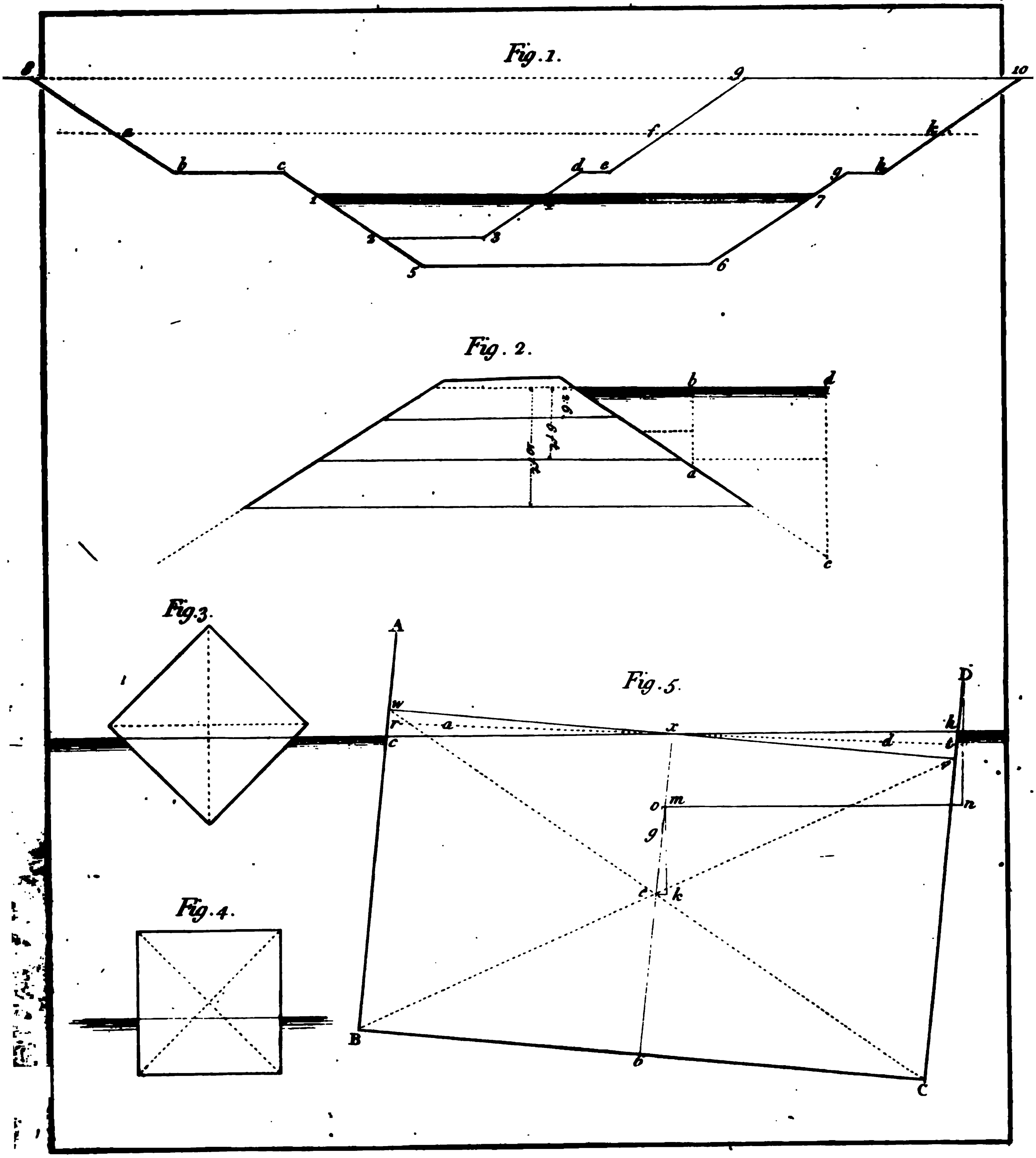
* If the declivity of the ground fhould limit the main Canal to boats of 12 feet width.

† A driver, two fteerers, and one to manage the ftop-ropes in going into a Lock.

‡ Similar in the leading features to the plan ingenioufly fuggefted by Dr. James Anderfon, in one of his late Publications.

FINIS.

Plate 1.



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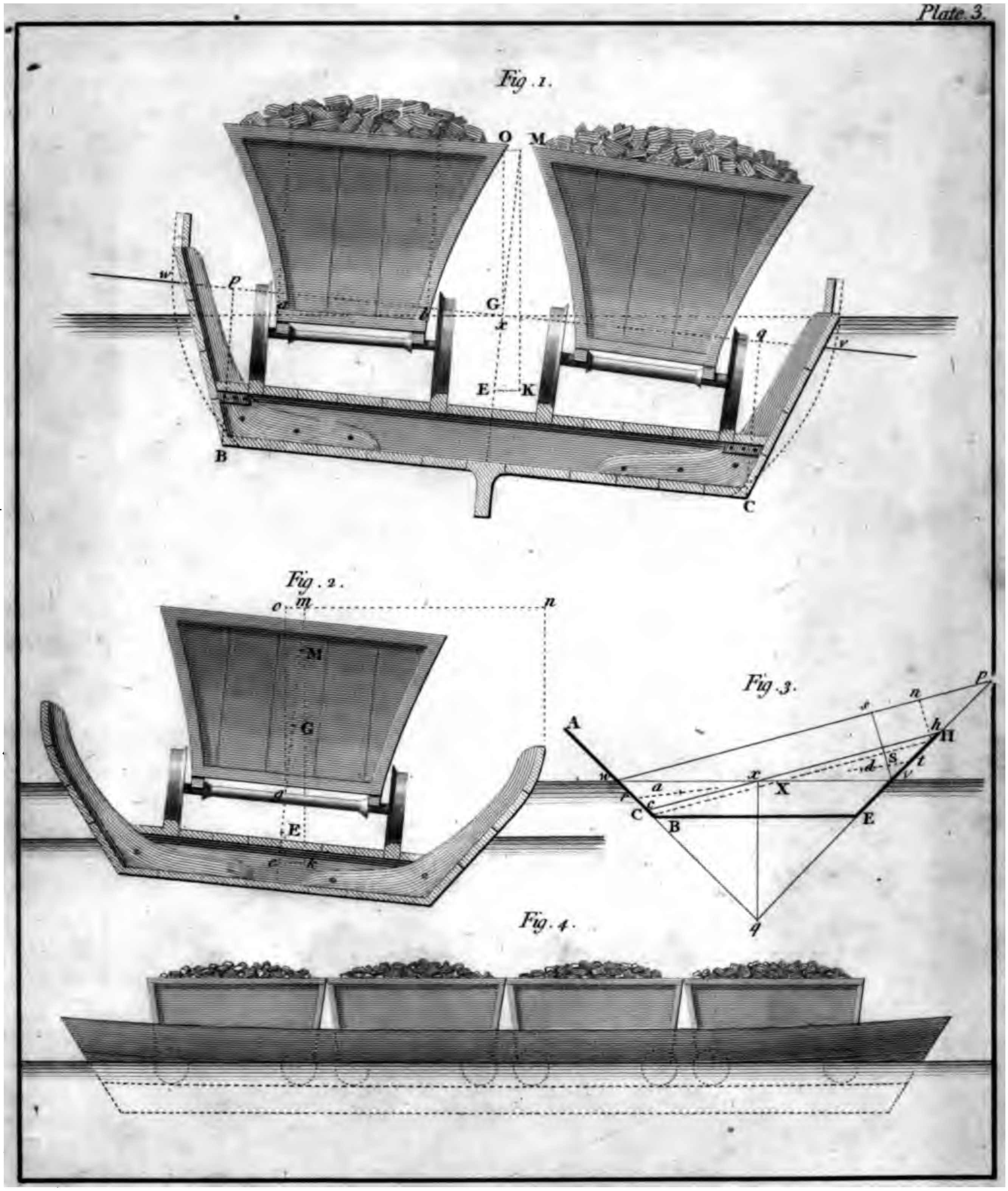

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Plate 4